METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 61 No. 363 JANUARY, 1960 Monthly: Two Shillings and Sixpence

NEWTON CHAMBERS AND DURGAPUR

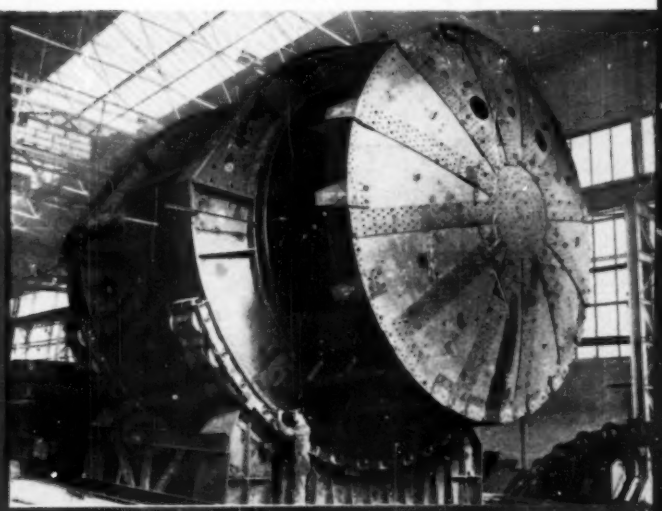
Newton Chambers, under contract to Wellman, Smith Owen Engineering Corporation Limited, have supplied the following equipment for the Indian Iron and Steel Works at Durgapur.

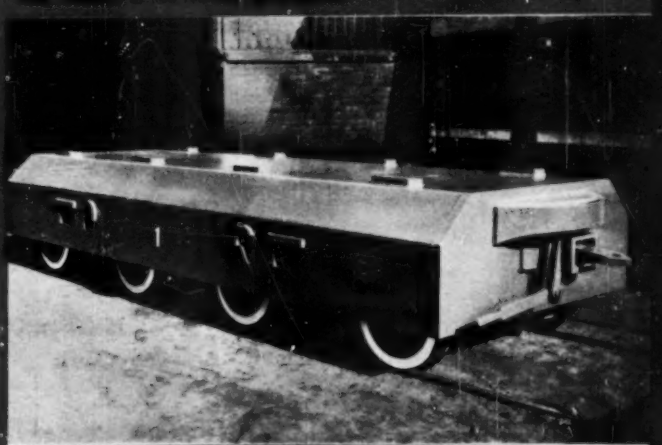
* 90 Ingot Casting Cars.
* 65 Charging Box Bogies.
* 260 Charging Boxes.
* 2 x 800 ton capacity Hot Metal Mixers.
* Structural steel work for 6 x 150 ton Ladle Cranes.

The orders were completed well ahead of schedule.

NEWTON CHAMBERS

ENGINEERING DIVISION · THORNCLIFFE · SHEFFIELD



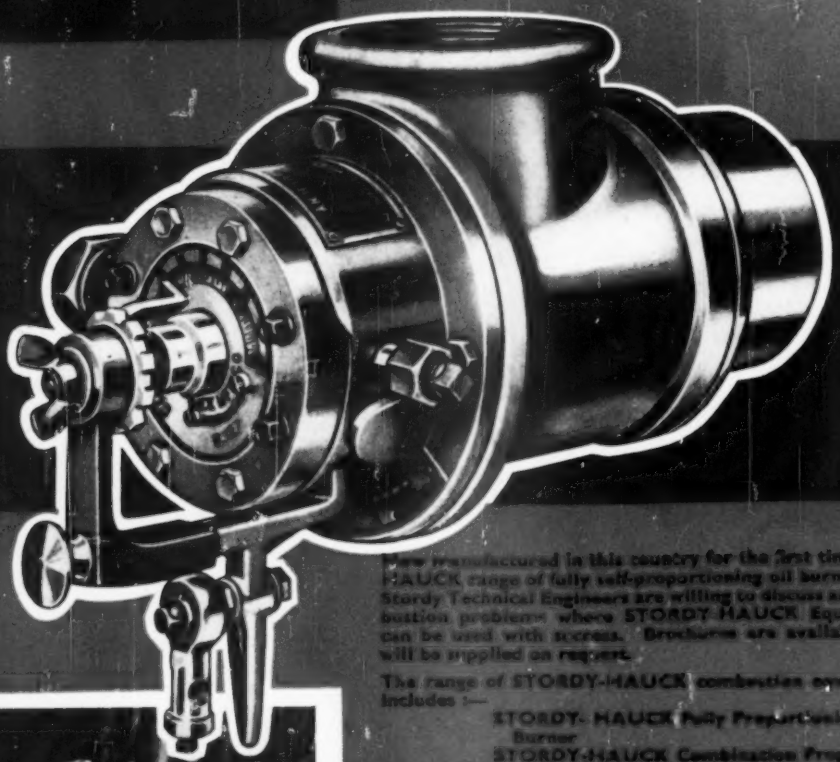


Charging Box Bogie complete with Charging Boxes

STORDY

SELF-PROPORTIONING

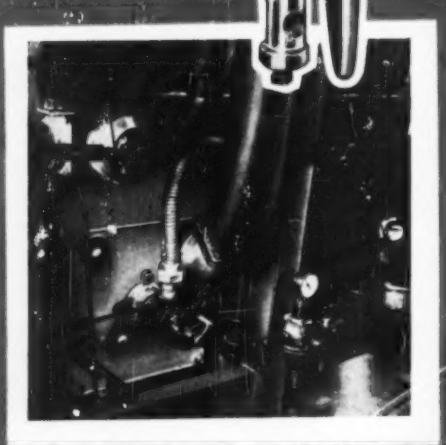
HAUCK OIL BURNERS



Now manufactured in this country for the first time—the HAUCK range of fully self-proportioning oil burners. Stordy Technical Engineers are willing to discuss any combustion problems where STORDY-HAUCK Equipment can be used with success. Brochures are available and will be supplied on request.

The range of STORDY-HAUCK combustion equipment includes :—

- STORDY-HAUCK Fully Proportioning Oil Burner
- STORDY-HAUCK Combination Proportioning Oil and Gas Burners
- STORDY-HAUCK Self Clean Metering Oil Valves
- STORDY-HAUCK Micro Cam Oil Valves
- STORDY-HAUCK Radiant Tube Burners (for either gas or oil)
- STORDY-HAUCK Vari-Pressure Burners
- STORDY-HAUCK Stranded Flame Units (for oil firing with excess air)
- STORDY-HAUCK Oil Pressure Regulators
- STORDY-HAUCK High Radiant Cone Gas Burners
- STORDY-HAUCK Adjustable Flow Valves (for gas and air)
- STORDY-SPENCER Turbo Compressors.



Application of Stordy-Hauck Proportioning Burner to Vitreous Enamelling Muffle Furnace, with automatic control to oil, primary and secondary air, the secondary air being pre-heated to 300° C.

STORDY ENGINEERING LIMITED

CLEVEDEN HOUSE · GOLDTHORN HILL · WOLVERHAMPTON. Tel. Wolverhampton 27541

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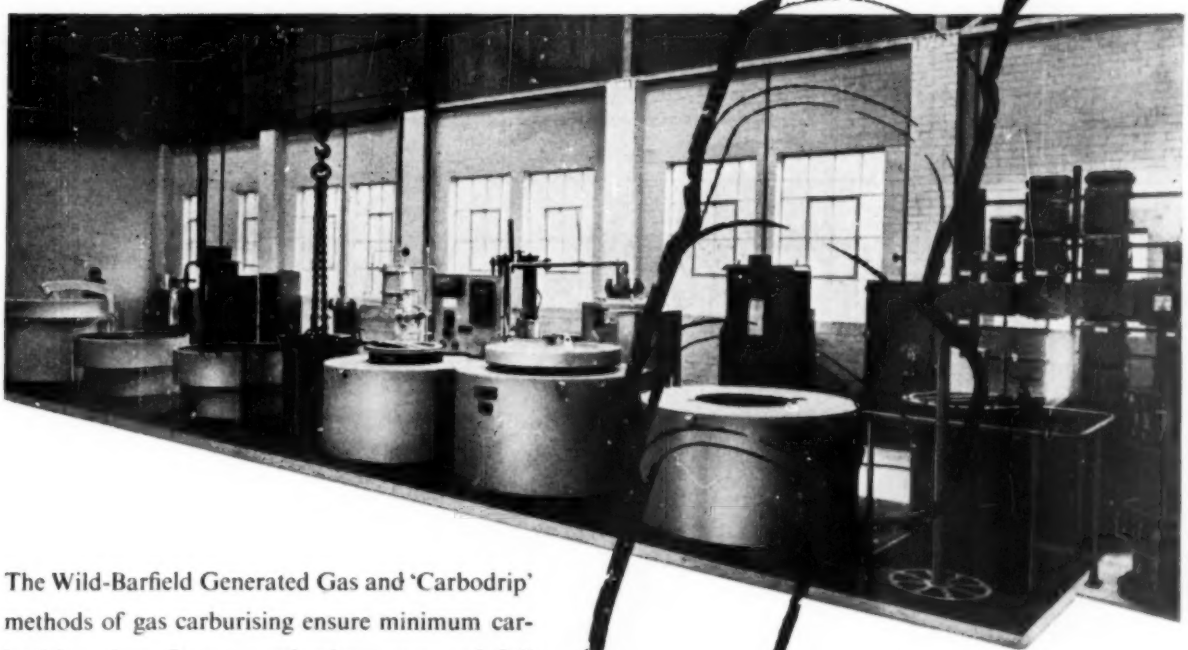

The Wild-Barfield Generated Gas and 'Carbodrip' methods of gas carburising ensure minimum carburising time, fastest production rates and full quality control. Write to us for advice on the application of gas carburising for your work.

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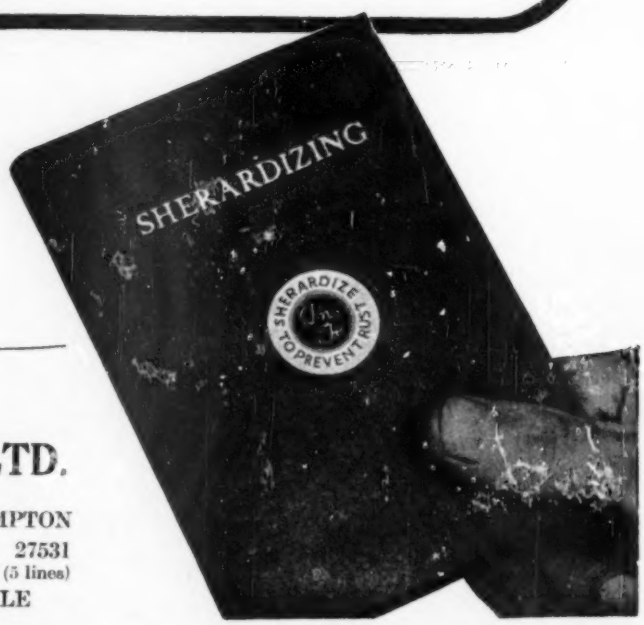

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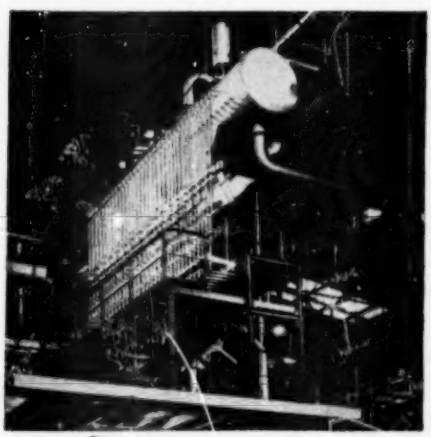
ALSO AT LONDON AND ROCHDALE

Reining - HOT COOLING

Open Hearth Furnace Door Frames (Thermo syphon). Steam produced approximately 2,000 lbs./hr. per door frame.

TYPICAL APPLICATIONS

Skid systems of 3 zone Continuous Reheating Furnaces (Forced circulation).
Steam produced approximately 20,000 lbs./hr. on 100 ton/hr. furnace.



This system of evaporative cooling, applicable to the water-cooled parts of all types of metallurgical furnaces has been fully developed and established in Germany during the last ten years by **Reining-Heisskühlung of Mulheim/Ruhr.**

The Reining system is now being applied in Great Britain and throughout the Commonwealth exclusively

by:—

Stein & Atkinson

1. Heat formerly lost in the cooling water is recovered in the form of saturated steam at any desired pressure. This heat recovery produces substantial fuel savings.

2. The quantity of cooling water required is limited to a make-up of boiler feed water corresponding to the quantity of steam consumed.

3. Failures of water-cooled parts due to blockage by deposits from untreated water are eliminated.

S & A

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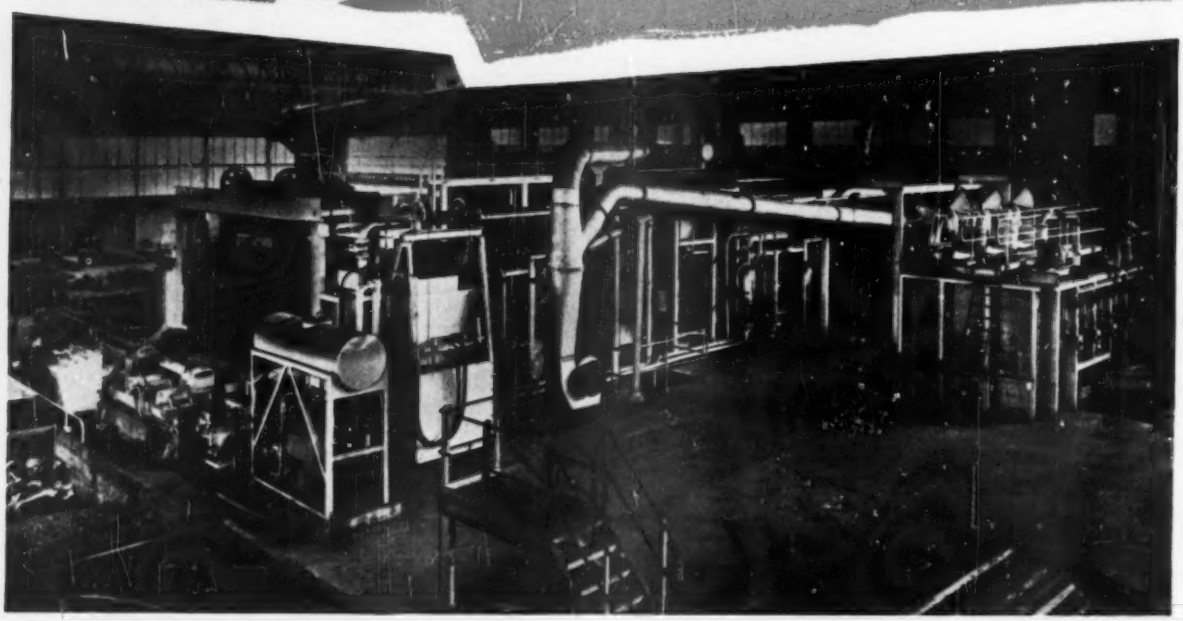
WESTMINSTER HOUSE, KEW ROAD, RICHMOND, SURREY

PRIEST

Oil Fired Continuous Billet Heating Furnace



We specialise in the design and construction of:—

Open Hearth Furnaces · Soaking Pits of all types · Continuous Multi-zone Bloom and Slab Re-heating Furnaces · Continuous Bogie type Ingot and Slab Heating Furnaces · Furnaces for Aluminium Melting, Coil Annealing and Slab Re-heating · Forge and Heat Treatment Furnaces · Stress Relieving Furnaces · Shipyard Plate and Bar Furnaces · Modern Lime Burning Kilns

The above Furnace is for reheating 3½ × 4in. billets 12ft. 0in long to rolling temperature. Specifically designed and zoned for efficient operation over a varying range of output up to a maximum of 25 tons per hour. Supplied to Samuel Fox & Company Limited, Stocksbridge Works, Sheffield, complete with electro-hydraulic pusher, side discharge pusher, extractor rolls and charging roller table.

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The last word in Furnace design

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CEMENTS, PLASTICS AND CASTABLES

From our extensive range of Refractory Cements, Plastics and Castables, covering a wide range of properties, we can supply the correct material for most industrial applications.

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Please ask for a copy of our No. 4 Pamphlet.

JOHN G. STEIN & CO. LTD. Bonnybridge. Scotland

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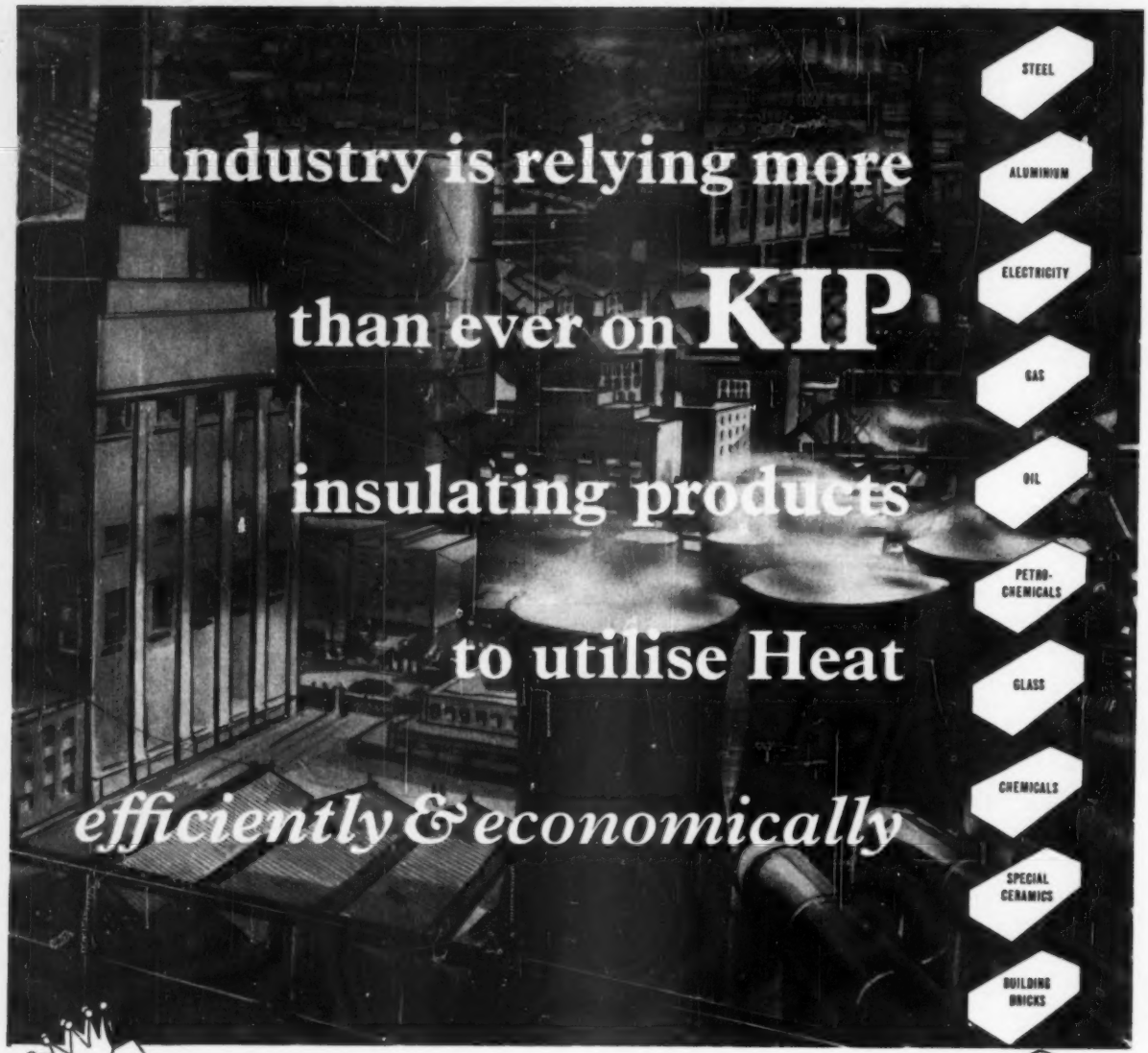

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KIP. 31

THERMOCOUPLE ALLOYS BY BRITISH DRIVER-HARRIS

We have been making thermocouple alloys at Cheadle for many years. Our experience tells us what people look for and our alloys provide it—stability, constant EMF values and long life.
Different temperature ranges call for different alloy combinations—and we provide them, including 'T1/T2', the only British-made base metal thermocouple for temperatures up to 1100°C. In cases where thermocouple wires are covered by a British Standard we produce them to conform to the Standard.
Accurate temperature measurement and control is something that cannot be left to chance. It is best left to Driver-Harris thermocouple alloys.

T1/T2 are wires of the nickel-chromium/ nickel-aluminium type for use at high temperatures and conform to the British Standard Specification 1827: 1952 within the usual tolerances. They also meet the requirements laid down in Air Ministry Specifications 1632 and 1705 covering extension leads.
Special Advance* wire (60/40 copper-nickel) is for use with copper up to 400°C and with iron up to 900°C. The EMF requirements of these two combinations vary according to individual specifications.

If you are interested in thermocouple alloys, then you may like to have a copy of Data Sheet No. 2 for reference.

Special Advance* wires can be selected in most cases to meet these varying demands within the usual tolerances.
Matched Advance* Iron Wires The non-availability of a Standard Iron and the variation of EMF properties experienced with different iron supplies result in some difficulty in reproducing thermocouple EMF properties. To overcome this difficulty we are now able to provide a Special Iron wire matched with Special Advance* to meet certain standard EMF requirements within the normal tolerances.

*REGD. TRADE MARK

BRITISH DRIVER-HARRIS CO LTD

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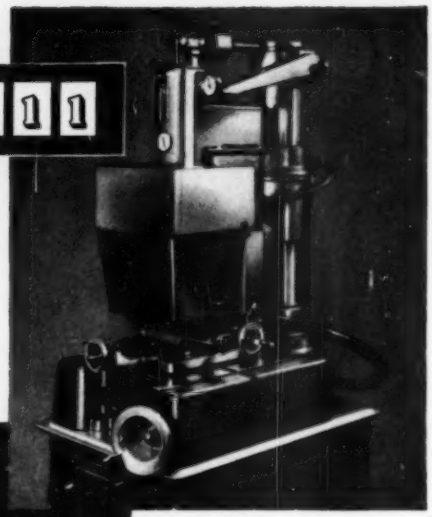
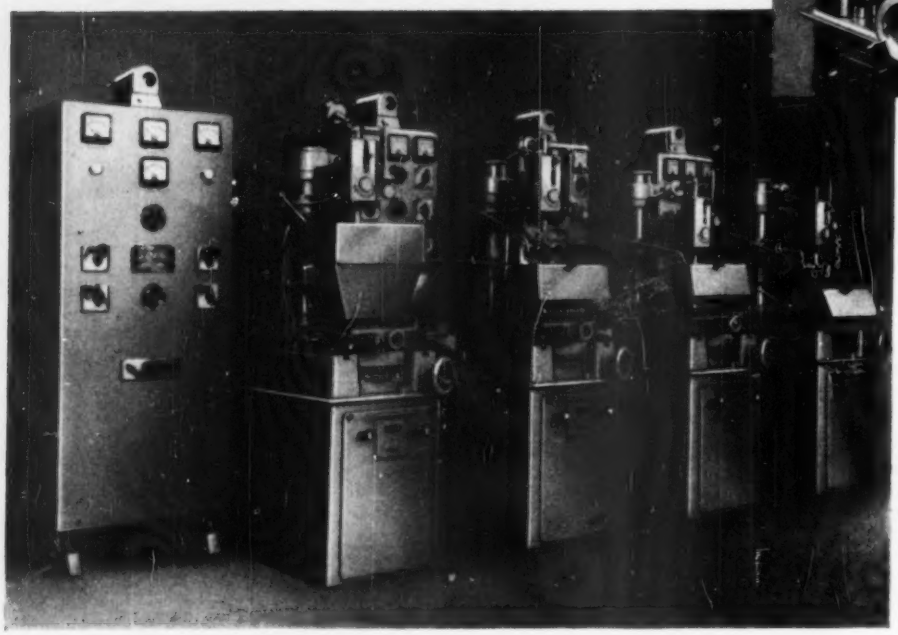
SPARCATRON Mk. III

6.5kW

The greatest advance since SPARCATRON established spark erosion machining on a commercial basis





Up to four spark-heads can be operated from one control cabinet. The current is automatically cut off when the electrode has penetrated the workpiece to a predetermined depth allowing one operator to supervise a number of heads.

CAPABLE of operating three to eight times as fast as the Mark II model, depending on the type of material and finish required, the latest SPARCATRON spark erosion machine, Mark III, has exceptional accuracy and increased capacity. The new design also features ease of access for loading the table and setting the servo-head and the facility for quick and accurate alignment of the electrode. SPARCATRON affords the best means of "cutting" intricate shapes, profiles, forms, or impressions in both hard and soft current-conducting materials.

SPS

SPARCATRON

Pioneered and established in the toolmaking industry for spark-machining and reconditioning press tools and dies and wire drawing and extrusion dies in cemented carbides and hardened steels. There are extensive applications for "cutting", reconditioning or altering flat and tangential form tools and similar components.

Manufactured by Impregnated Diamond Products Ltd.

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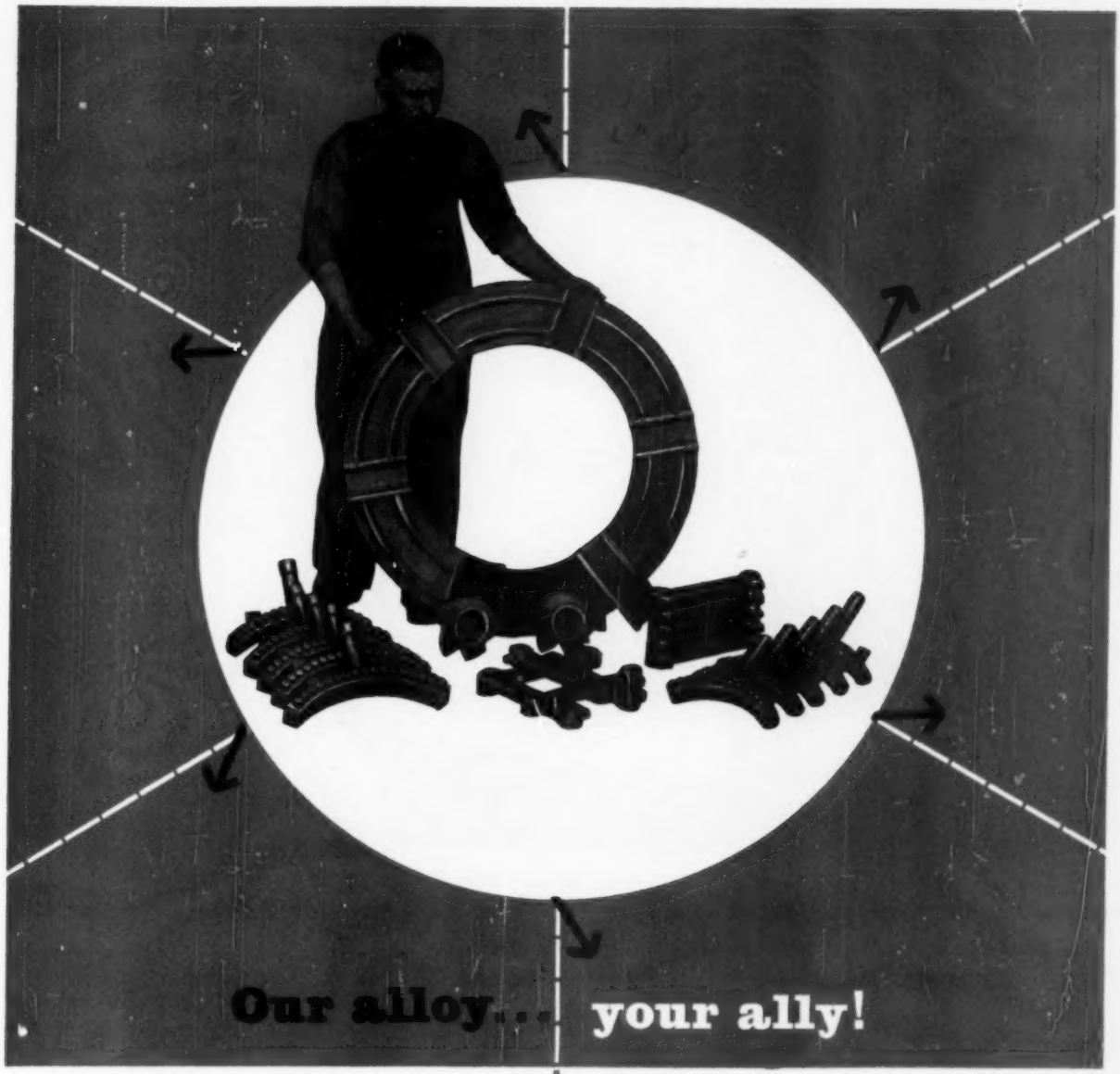

The Thompson L'Hospied service embodies much more than the production of accurate and consistently fine heat-resisting castings. Through their close association with the furnace industry they have first-hand knowledge of its requirements and unequalled facilities for testing under actual conditions.

Added to these unique advantages is the specialised knowledge acquired during over twenty-five years in the trade. Thompson L'Hospied advice on alloys and design is widely sought and freely given to customers in every industry where heat or chemical treatment plays a part.

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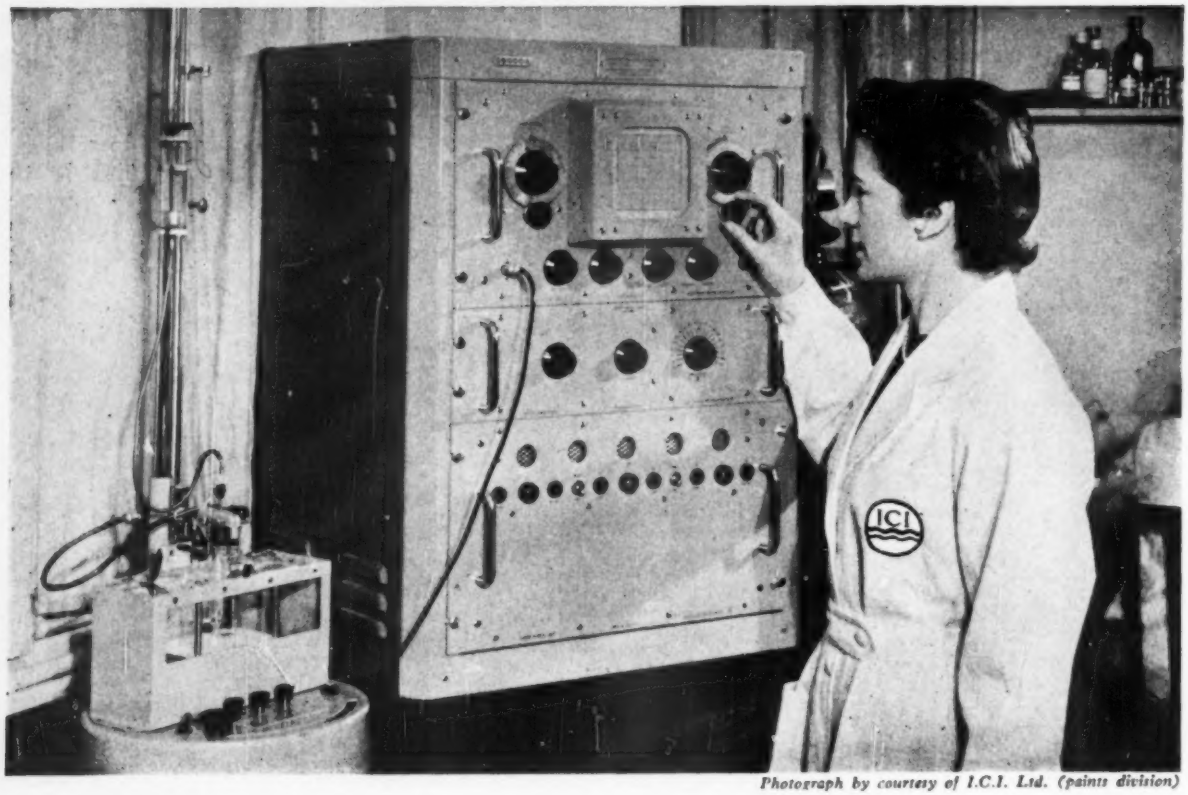

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Analysts all over the world have found how easy it is to get rapid and accurate analyses with our Cathode Ray Polarograph. It is quick in action, gives direct or derivative readings, and has that extra sensitivity you so often require.

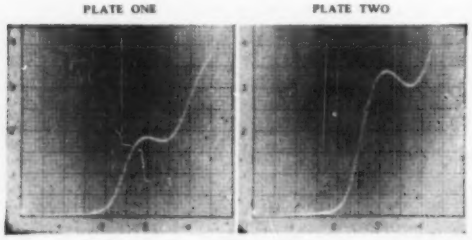
Its easily readable peak polarograms repeat every seven seconds. Your laboratory is wasting expensive time without this indispensable instrument.

SPECIFICATION

DISPLAY. six-inch diameter cathode ray tube, with a 9cm. square graticule printed on its flat, long persistence screen.

VOLTAGE SWEEP. Rate: 0.3 volt per second (fixed). Range: 0.5 volt per sweep approximately (fixed). Start Potential: + 0.5 volt to -2.0 volts (variable). Sweep Time : One polarogram per mercury drop with seven second repetition.

PLATE ONE PLATE TWO



TYPICAL APPLICATION FOR CATHODE RAY POLAROGRAPH

Determination of Cyanide in Effluent Sample. Introduce 5 ml. sample into two 10 ml volumetric flasks, into one flask add 0.2 ml. of a standard cyanide solution. (50 µg/ml. CN^-), and make each up to the mark with 0.2N NaOH. Shake well. Transfer 5 ml. from each flask into polarographic cells, and de-aerate with nitrogen for 3 mins. Record the polarograms applying anodic oxidation on start potential -0.4V and scale factor 1.0.

x µg CN^- + 5 µg CN^- = 34 divisions (Plate 2)
x µg CN^- = 18.5 divisions (Plate 1)
∴ 5 µg CN^- = 15.5 divisions

$$x = \frac{5 \times 18.5}{15.5} \ \mu g$$

$$x = 6.0 \ \mu g$$

Volume of sample in cell = 2.5 ml.
∴ Concentration of CN^- in sample = 2.4 µg/ml.

Send now for "Trace Techniques" just published containing 30 new polarographic methods. Price 25/- post paid. (U.K. only.)

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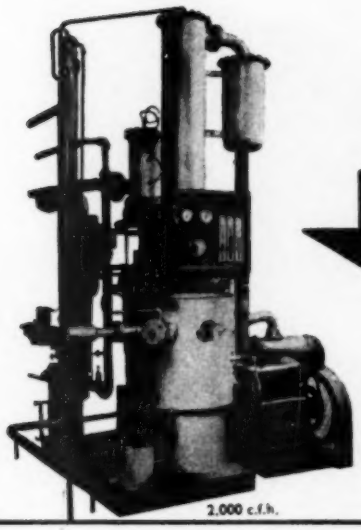
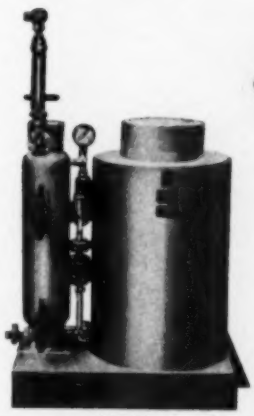
Atmosphere generators with a wide range of applications in many industries. In the metal industry for bright annealing, brazing, sintering, gas carburising, bright hardening, etc.



2,000 c.f.h.

GmvL Ammonia Cracker

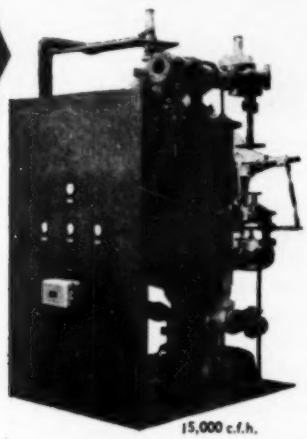
For bright treatment of stainless acid resisting and heat resisting steels, and for brazing and sintering generally.



150 c.f.h.

Gibbons Sub-X Inert Gas Generator

A highly efficient and compact producer of inert gas, operating on standard gaseous fuels and distillate grades of fuel oils.



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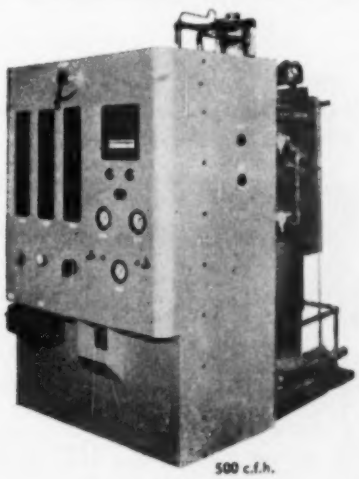
G.A.A. Endothermic Generator

For gas carburising, dry cyanide treatment, etc Automatic response to variations in demand while maintaining correct gas/air ratio.



500 c.f.h.

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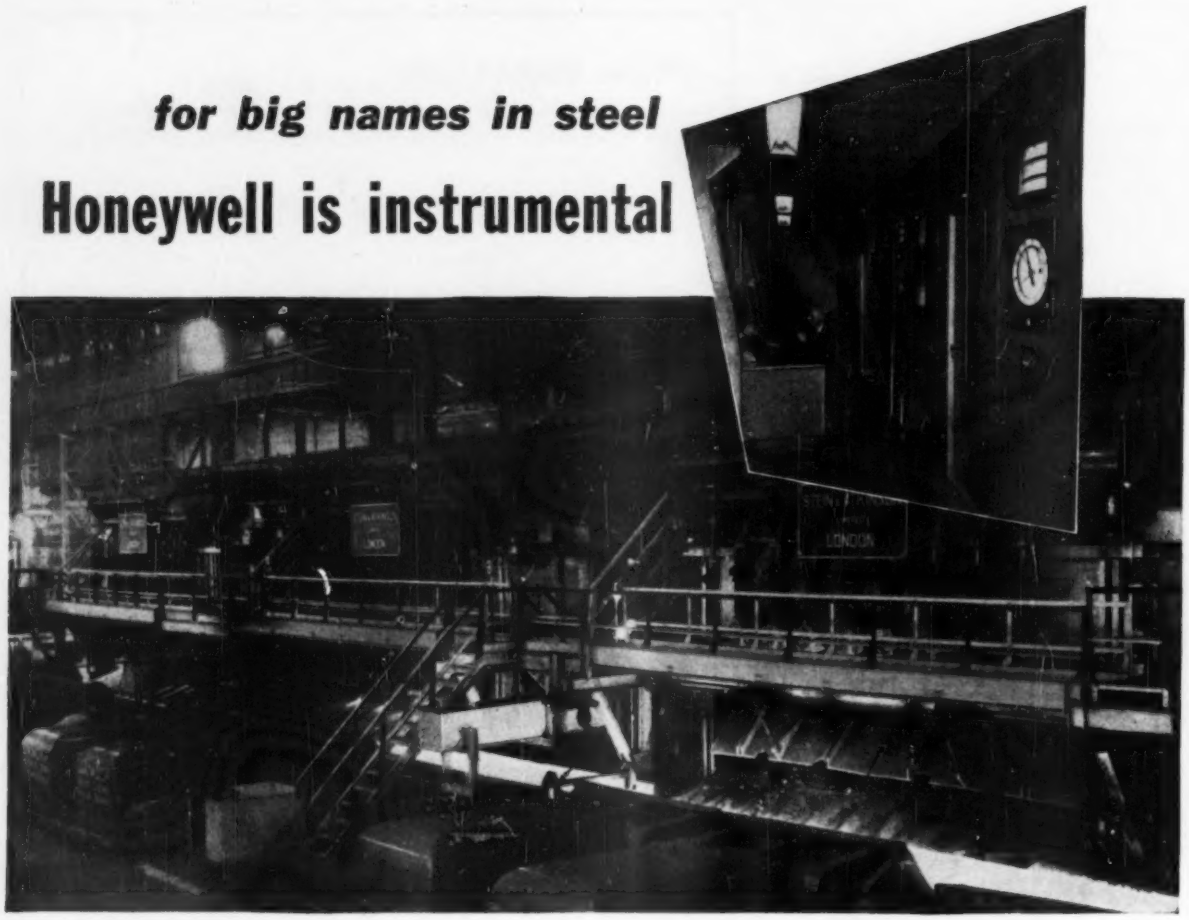
for big names in steel

Honeywell is instrumental



Flexible Honeywell controls regulate oil and gas fired zone temperatures on reheaters. Alternative combined controller settings can be quickly selected from a control knob at the desk.

There is an atmosphere of confidence in a big steelworks operating under Honeywell control. At the Ebbw Vale works of Richard Thomas and Baldwins, each 7-ton slab of red-hot steel bears an invisible guarantee as it moves past the instrument panel on its way from the reheating furnaces to the rolling mill:

a guarantee of precision; *optimum temperature distribution exactly reproduced . . . ideal surface quality from close control of furnace atmosphere.*

a guarantee of economy; *each slab costs less to heat when every calorie is harnessed by automatic fuel flow control.*

And the range and flexibility of Honeywell instruments ensure that these units can be built into new plant conveniently, without prejudice to plant design. This is why the big names in steel . . . Richard Thomas and Baldwins . . . Steel Company of Wales . . . Steel Peech and Tozer . . . Colvilles . . . come to Honeywell for their instrumentation.

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Address of your nearest branch office ☐
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Honeywell

First in Control

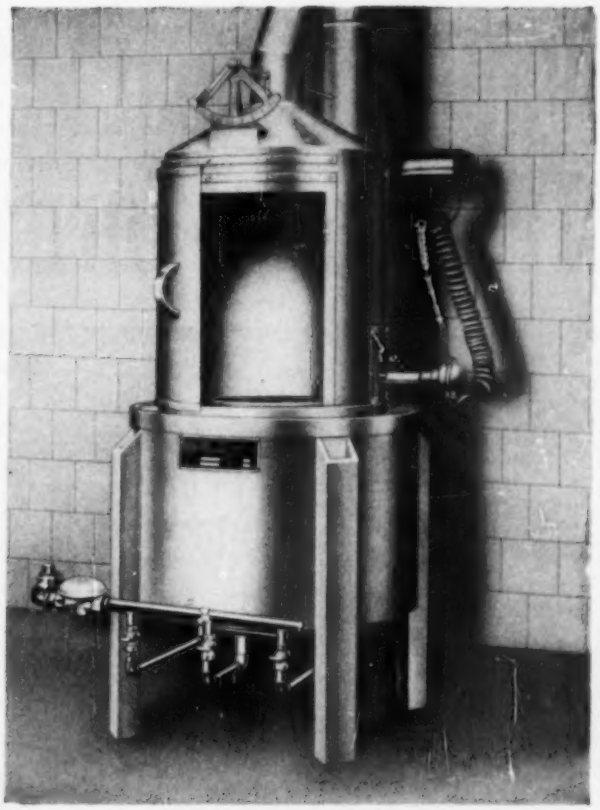
SINCE 1885

GAS BLAST COMBINED FORGE AND BRAZING HEARTH

Complete with Motor Driven Positive Air Blower, two Gas Blast Blow Pipes and one Gas Blast Burner. Suitable for Tube bending up to 1 in. diameter.

Size of Hearth, 20 in. × 20 in. × 4 in.

Gas Consumption, 200 cu. ft. per hour maximum.



NATURAL DRAUGHT GAS FIRED SALT BATH SUITABLE FOR CYANIDE OR NEUTRAL SALTS

Suitable for temperatures up to 900° C.

Obtainable in the following sizes :
8 in. dia. × 8 in. deep, gas consumption 300 cu. ft./hr.
8 in. dia. × 10 in. deep, gas consumption 350 cu. ft./hr.
10 in. dia. × 12 in. deep, gas consumption 400 cu. ft./hr.

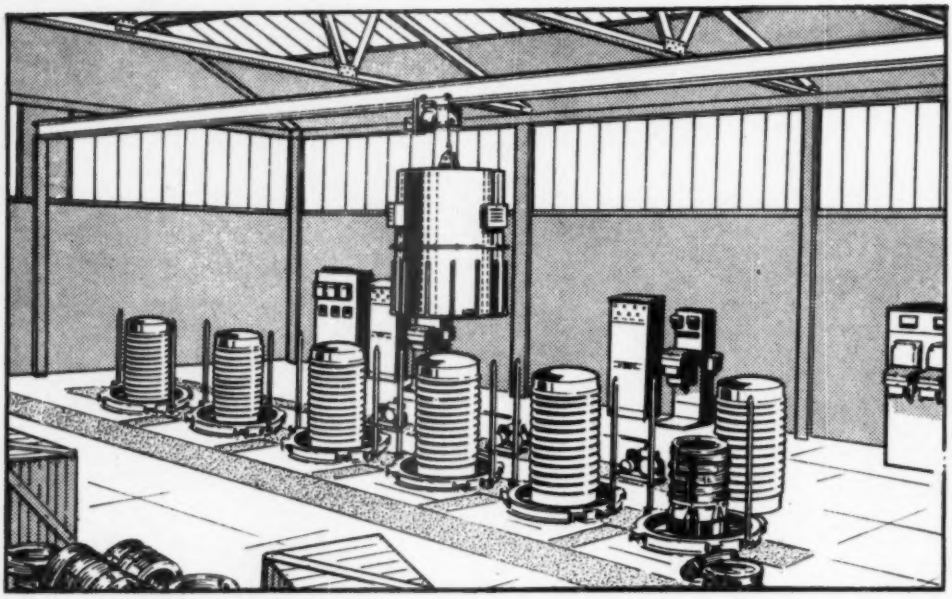
Time to heat up—1½ hours.

Manufactured by

KASENIT LTD

7, HOLYROOD STREET · BERMONDSEY · LONDON, S.E.1

Vacuum Heat Treatment Furnaces



Horizontal or Vertical furnaces for Vacuum annealing, degassing, sintering and brazing

For Vacuum heat treatment process EFCO offer a range of furnaces including both hot retort and cold retort types. Various pumping systems can be supplied to give the evacuation speed and ultimate degree of vacuum required.
EFCO bell type vacuum furnaces are well suited to the bright annealing of copper wire or strip in coils.
An 85 kW Furnace with 6 bases can give an output of 35 tons per 120 hour week.

EFCO

BEST OF THE WORLD'S CURRENT FURNACE DESIGNS

ELECTRIC RESISTANCE FURNACE CO. LTD
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Associated with Electro-Chemical Engineering Co. Ltd.

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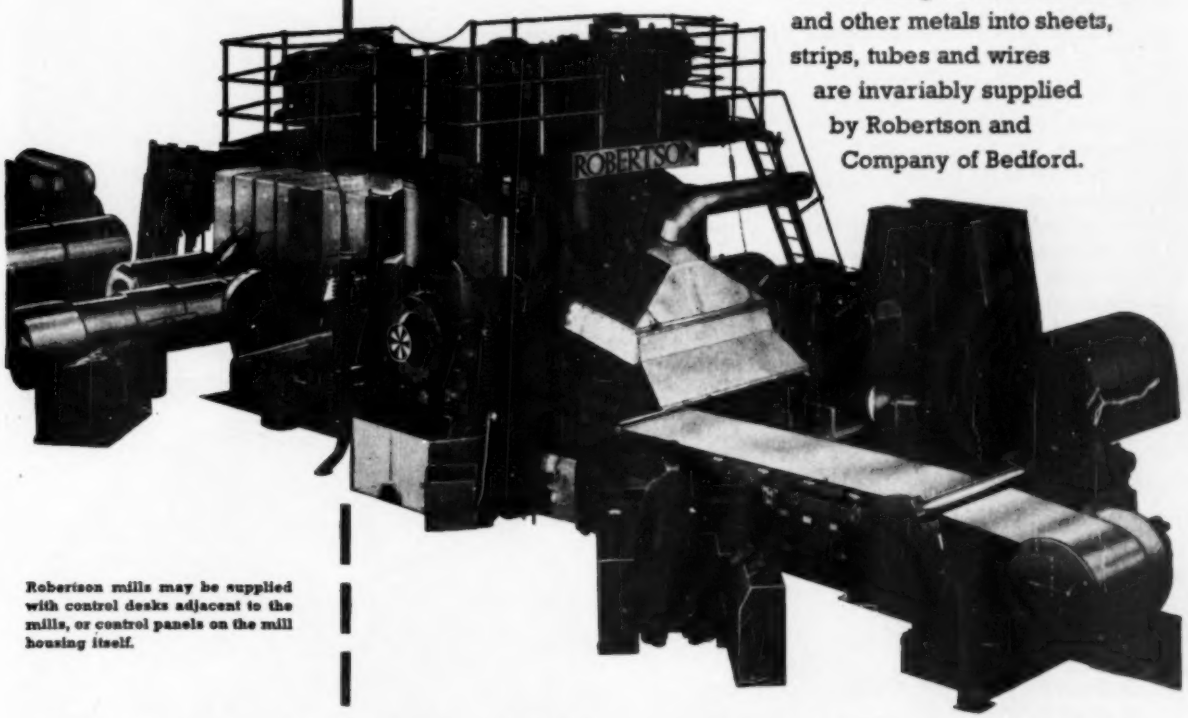
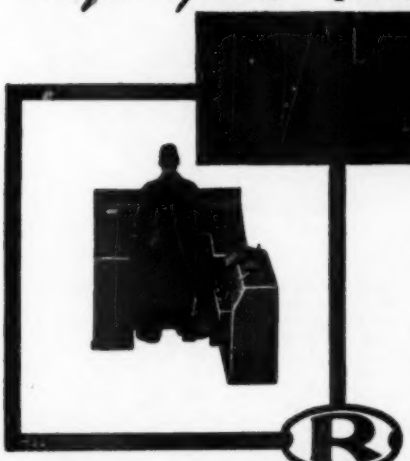
MAN AND MACHINES

Research and development, always keeping abreast and often ahead of the times, has been Robertson's policy since the days of their first machines designed in 1907 to help man increase production. For over 50 years, the high standard of design and quality finish of their products have kept the name 'Robertson' synonymous with the high class machines demanded by master craftsmen in metals. Today, the finest machines for reducing steel, aluminium and other metals into sheets, strips, tubes and wires are invariably supplied by Robertson and Company of Bedford.



Robertson mills may be supplied with control desks adjacent to the mills, or control panels on the mill housing itself.

High speed Aluminium Strip Finishing Mill



For thicknesses from : 0.25 in. (6 mm.) to under .012 in. (0.30 mm.)
Max. Width : 53 in. (1,300 mm.) Max. Speed : 1,000 ft. (300 m.) per min.
This Robertson Four-High Reversing Cold-Rolling Mill was recently supplied to the Société Industrielle de l'Aluminium, Duffel, Belgium, for finishing hot rolled aluminium and light alloy strip. It is the most efficient high speed mill of its kind yet installed.

W. H. A. ROBERTSON & CO. LTD., BEDFORD, ENGLAND

LICENSEES FOR THE BUILDING OF SENDZIMIR COLD REDUCTION MILLS AND PLANETARY HOT MILLS, HALLDEN GUILLOTINE AND ROTARY FLYING SHEAR MACHINES AND TORRINGTON METAL WORKING MACHINERY. W.T. 308

Baldwin Atomat Nucleonic Thickness Gauges

ACCURATE, CONTINUOUS, NON-CONTACT INSPECTION

SAVES MATERIAL, LABOUR AND TIME!

The Atomat Principle

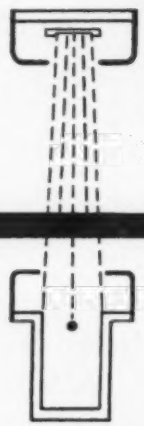
RAY SOURCE

MATERIAL

RAY DETECTOR

Amount of rays passing through material indicates thickness or weight per unit area.

That's the very basic explanation of the Atomat principle. There are three main gauges; the Atomat Cold Strip Gauge, the Hot Strip Gauge and the Beta Gauge.
In addition there are special purpose variations, made to meet the requirements of many different industries.



HERE'S WHAT AN ATOMAT GAUGE CAN OFFER YOU

- **Time and material saving both in production and setting up**
- **High accuracy**
- **Calibration in your usual units of measurement**
- **Continuous readings for materials in constant production**
- **Auto standardisation and control if you require**
- **Minimum maintenance**

Baldwin Atomats are already boosting production and cutting costs in the paper, metal rolling, rubber and plastics industries. Highly successful applications also include the measuring of selenium on aluminium, coatings of paint and lacquers, density of wood chips, coatings of grit on abrasive papers and padding and resin impregnation in the textile industry. But the potential of Baldwin Atomat Nucleonic Gauges has hardly been tapped.
Is there a place for them in your plant?

INSTRUMENT DIVISION

Send for the Baldwin Brochure MA/124. It gives full information on Atomat Gauges clearly and concisely.

BALDWIN INDUSTRIAL CONTROLS

Baldwin Instrument Company Limited, Dartford, Kent A Harper Group Company

Tel. : DARTFORD 6411 & 2948 *Cables and Telex : Baldwin, Dartford*

B23

Make the most of O_2 techniques

Imagine Hamlet without the Ghost! Difficult, isn't it? Well to some extent it's as difficult to contemplate operating the new oxygen steelmaking techniques without refractories researched and designed for this job. Through its extensive Research Department, General Refractories have developed new refractories to deal with these many new problems raised by oxygen steelmaking. For instance, Ferroclad '100' EE reduces wall lining wear in Open Hearth and Electric Steel Units — Ferroclad '30' EE and Densyl give increased roof life in Open Hearth furnaces — Spinella 'R2' offers exceptional advantages in full open hearth roofs — Spinella 'A' and Sillmax have solved problems in regenerator roofs and checker filling—GR 341 Dolomite bricks provide perfect linings for L.D., Kaldo and Rotor convertors, ladles, etc.

GR Technical Service Department is available for consultation by users in the selection and application of these and other refractories.

Everything in GR *Furnace Linings*

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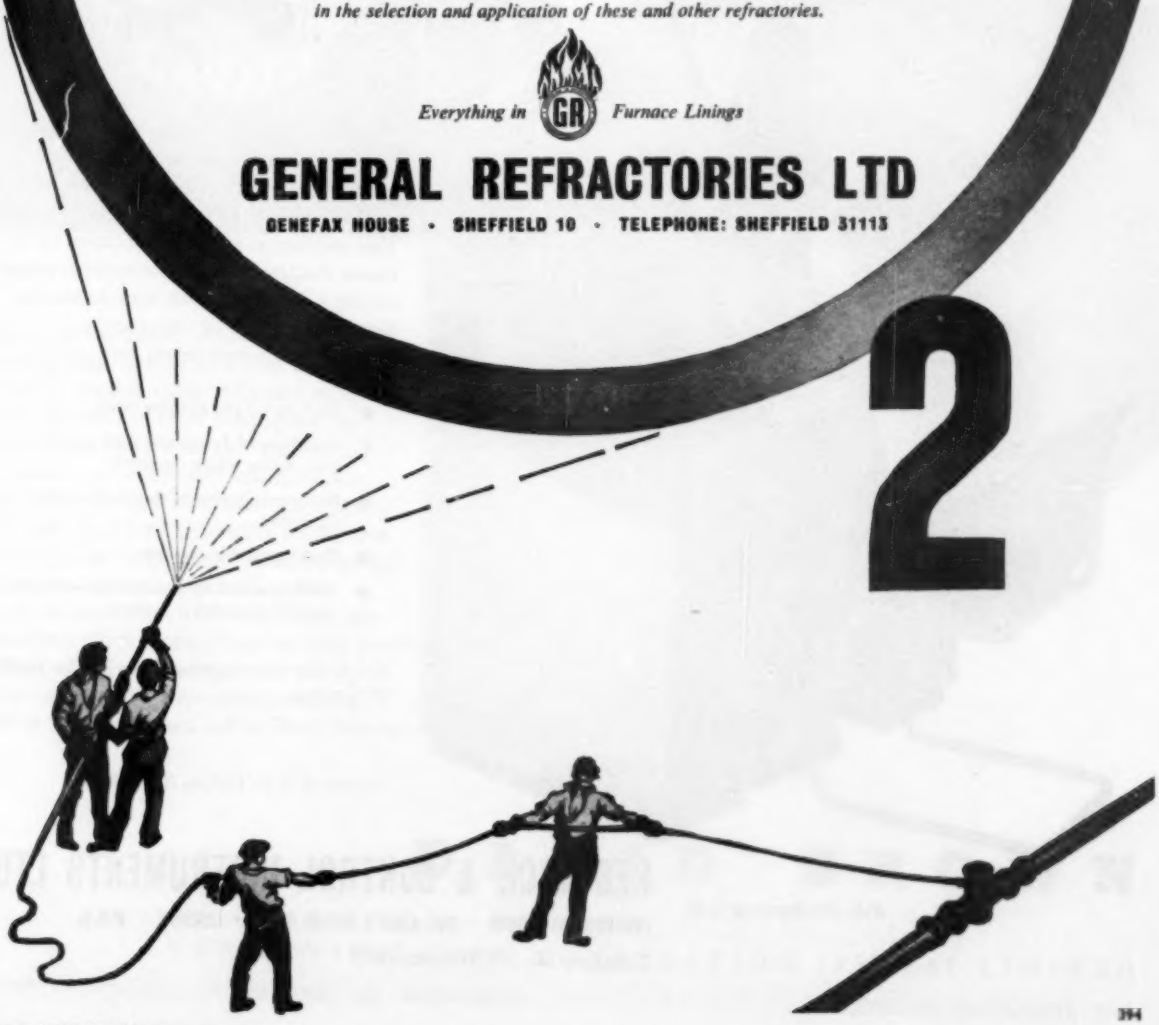

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Low cost

Electron Microscope!

Philips EM 75B is a simply operated electron microscope with resolving power of 50Å specially designed to supplement optical microscopy in the range of 1200 to 3000 diameters. This instrument gives magnification up to 12,000 diameters on to photographic plates, making a further magnification to 120,000 diameters possible by enlargement. Features of this instrument are:

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- Rapid specimen change
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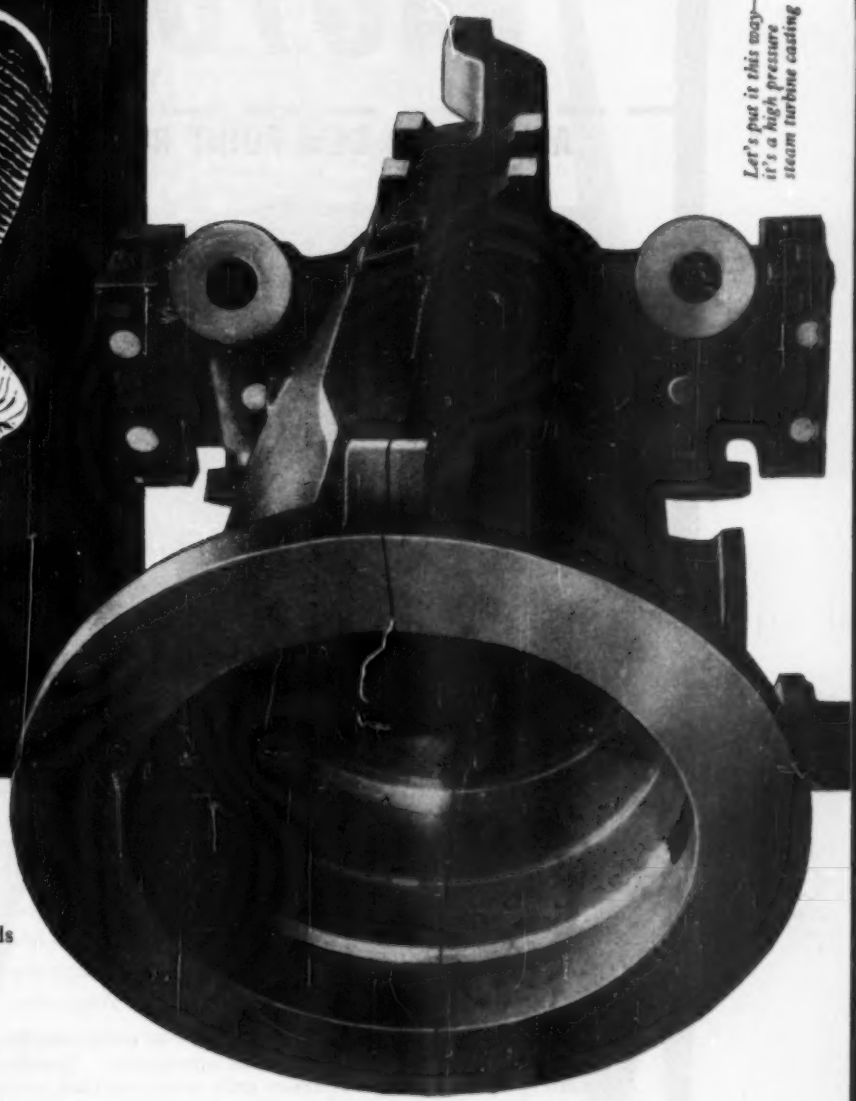
Brown Magic



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There is no witchcraft, really, about the unvarying high quality of David Brown castings — though there are many other kinds of craft involved in their production. At the Penistone Foundries, the crafts of the steel maker, pattern maker and moulder are brought together and, with other skills, are co-ordinated into a complex production unit of supreme efficiency. Backed by unique metallurgical resources and using the most up-to-date plant and techniques, this organisation offers a completely reliable service for all types of steel casting.

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DAVID BROWN

THE DAVID BROWN CORPORATION (SALES) LIMITED

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AUTOCARB

AUTOMATIC DEW POINT RECORDERS AND CONTROLLERS

Signal Controller

Recorder Controller

Autocarb systems automatically adjust the flow of air or enriching hydrocarbon to the furnace or generator in direct response to the dew point of the atmosphere. Specified conditions are automatically maintained. Autocarb systems are simple compact units which indicate, record and control the dew point of gas atmospheres in continuous or batch furnaces and atmosphere generators. They can control dew points to within plus or minus two degrees. On continuous furnaces separate zones of atmosphere control can be established and automatically maintained. If manual control is preferred, the Autocarb line includes simple recorders or indicators. On batch furnaces the Autocarb system will maintain the desired carbon potential for each temperature established in the heating chamber. On endothermic gas generators Autocarb systems automatically and continuously compensate for fluctuations in the composition of the reaction fuel gas supply and the humidity of the reaction air. This keeps constant the dew point of the product gas.

BRITISH FURNACES LTD.

CHESTERFIELD

ASSOCIATED WITH SURFACE COMBUSTION CORPORATION, TOLEDO, U.S.A.

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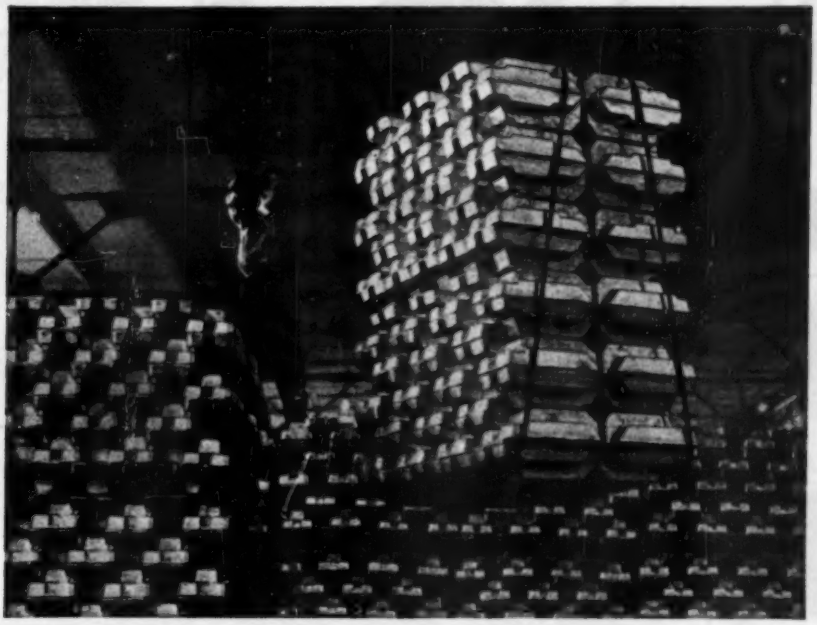
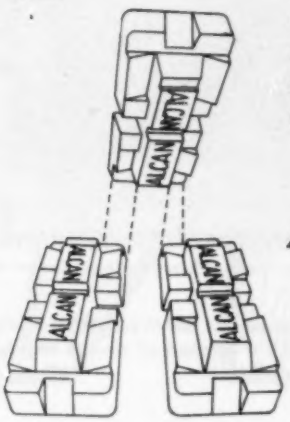


a new form of ingot for easier, speedier, safer handling

ALCAN 'TRI-LOK' ingots readily separate by lifting, though when stacked they interlock three ways and provide a bundle ready for fast handling by fork lift truck.



ALCAN (U.K.) LIMITED (specialists in aluminium ingot) have introduced a new and brilliant development in ingot design, the 'TRI-LOK.' This ingenious inter-locking shape enables ALCAN ingots to be stacked more compactly with greater safety and more speed because they 'mate' one to another – and resist lateral and lengthwise displacement. The consequent ease of handling has already given measurable cost savings in loading and storage operations to many ALCAN customers.

ALCAN
TRI-LOK

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Telephone: Mayfair 9721 · Cable: Alcanuk · London
BIRMINGHAM: Gazette Buildings · Corporation Street
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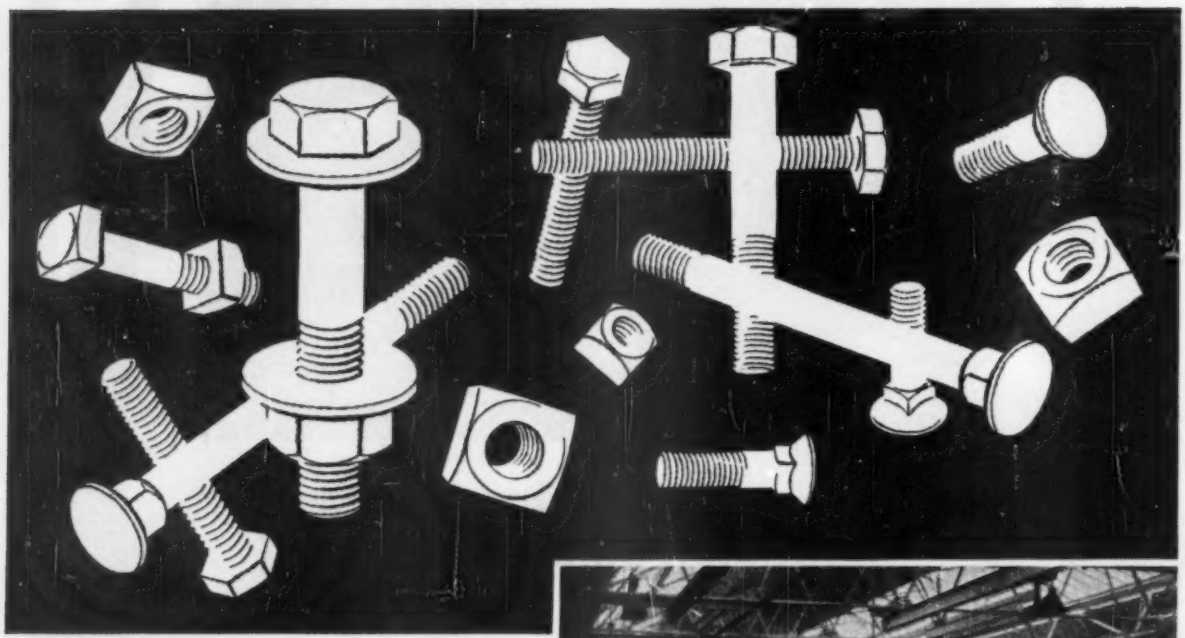
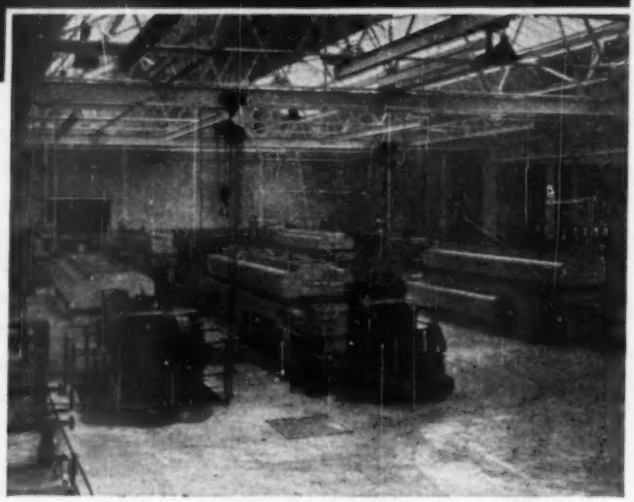
ALCAN
ALUMINIUM LIMITED OF CANADA

GKN AND G.W.B.



Two sets of initials, both of which stand for reliability. Millions of nuts, bolts, rivets and fasteners of all types leave the Darlaston (Staffs.) works of Guest, Keen & Nettlefolds (Midlands) Limited every week. Accurately made from the best quality materials, heat-treatment plays an important part in ensuring that they conform to the highest specifications.

Among the latest equipment installed by G.W.B. Furnaces Limited are three completely continuous lines of Hardening and Tempering furnaces. Each line comprises: 30 cwts. Loading hopper—De-greaser—Hardening furnace—Continuous quench extractor—Loading hopper—De-greaser—Tempering furnace—Continuous quench extractor. The Tempering units can also be used independently as Hardening furnaces if required. Each furnace has an output of 5/6 cwts. per hour, and the whole installation is served by two men only, one to supervise the general operation and one fork truck driver who, among his other general factory duties, loads the hoppers and conveys the full bins of heat-treated components to the Packing Dept.



G.W.B. Hardening & Tempering Furnaces at Guest, Keen and Nettlefolds, Darlaston.

"If it's a matter of how to fasten one thing to another, get in touch with GKN." If it's a question of electric heat-treatment or melting equipment, consult G.W.B.

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Associated with Gibbons Bros. Ltd., and Wild-Barfield Electric Furnaces Ltd.

GWB217

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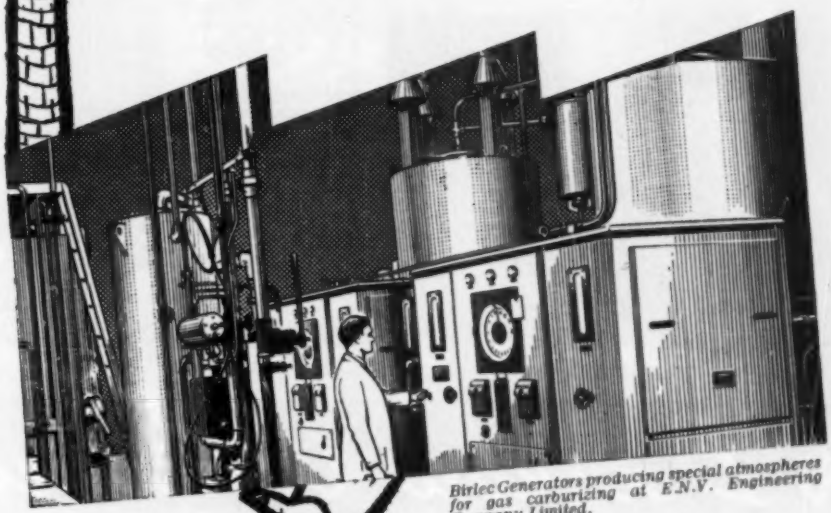
carry weight in industry



Birlec Generators producing special atmospheres for gas carburizing at E.N.V. Engineering Company Limited.

Propane and Butane are now available to industry from the great British refineries of the Shell, Eagle and BP Groups. They are petroleum gases delivered and stored as liquids under moderate pressure.

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It is widely used for gas carburizing, carbonitriding and bright annealing of ferrous and non-ferrous metals.

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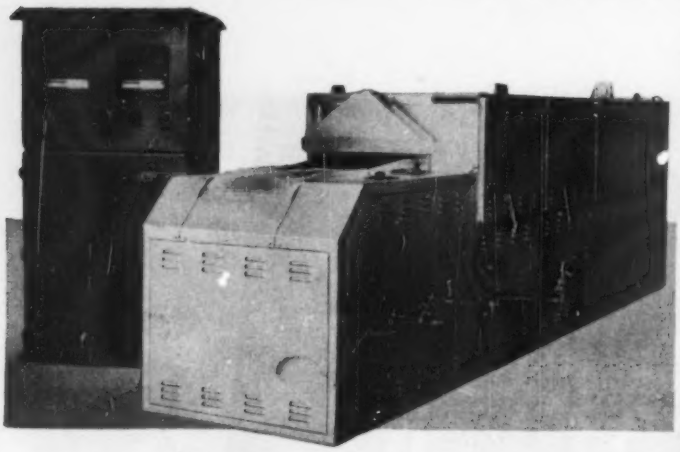
STANDARD & SPECIALS



Illustrations show typical units from the 'B-W' range of electrically - heated Furnaces.

On right Standard type vertical forced circulation Furnace for temperatures to approx. 750°C.

On left Continuous type Furnaces built to special requirements.

OTHER 'B-W' PRODUCTS INCLUDE: OVENS, METAL POTS, IMPREGNATING PLANTS, TINNING BATHS, HOT OIL CIRCULATORS, WAX AND COMPOUND KETTLES AND DIP TANKS.

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Would metals with such characteristics make your production better? Wild-Barfield—NRC vacuum melting furnaces enable you to develop materials specially suited to your needs. Backed by the experience of the National Research Corporation, who have built and operated more high vacuum furnaces than any other company in the world, Wild-Barfield—NRC vacuum equipment covers most needs. Write for details of the range.

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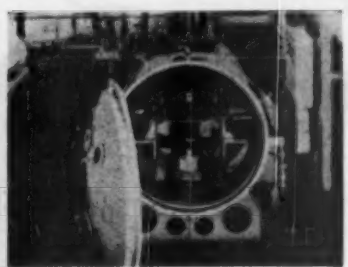
NRC is the trade-mark of the National Research Corporation, registered in the United States Patent Office.

COULD A VACUUM FURNACE DO THE SAME FOR YOUR PRODUCTS?

Model 2555 Vacuum Induction Furnace with melting capacity of 50 pounds of steel. Other standard furnaces have capacities of 12 to 3,000 pounds.



Model 2705 Non-Consumable Arc Skull Furnace with a capacity of 50 pounds of titanium. Other standard vacuum arc furnaces have capacities of 8 to 10,000 pounds of titanium.

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for all heat-treatment purposes

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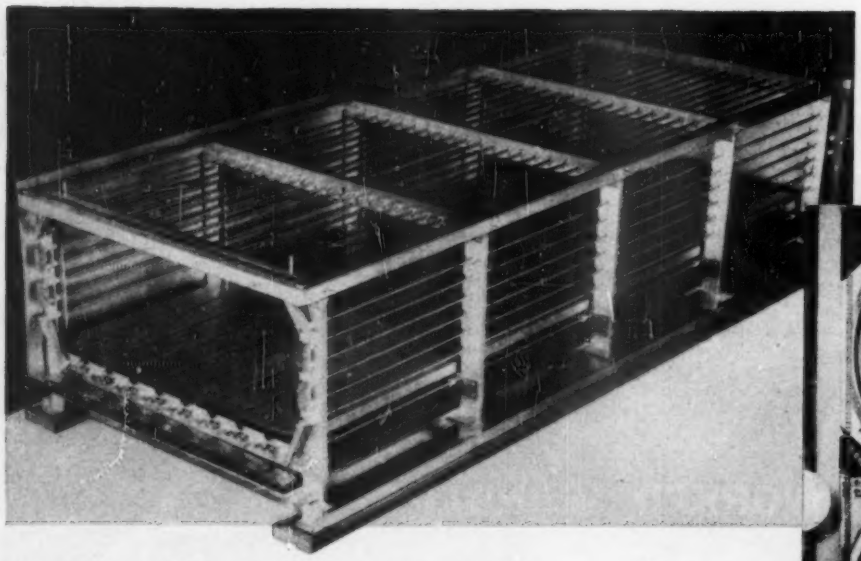
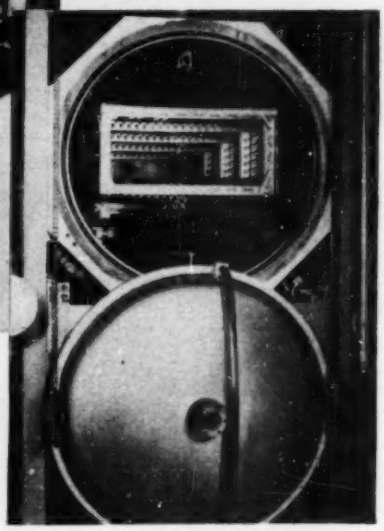


High Temperature
VACUUM FURNACE



Interior of high temperature Vacuum Furnace constructed from MOLYBDENUM SHEET with TUNGSTEN ROD Heating Elements

Length 4 ft. ★ Width 16 ins. ★ Depth 6 ins.

Furnace chamber open, showing interior in position.

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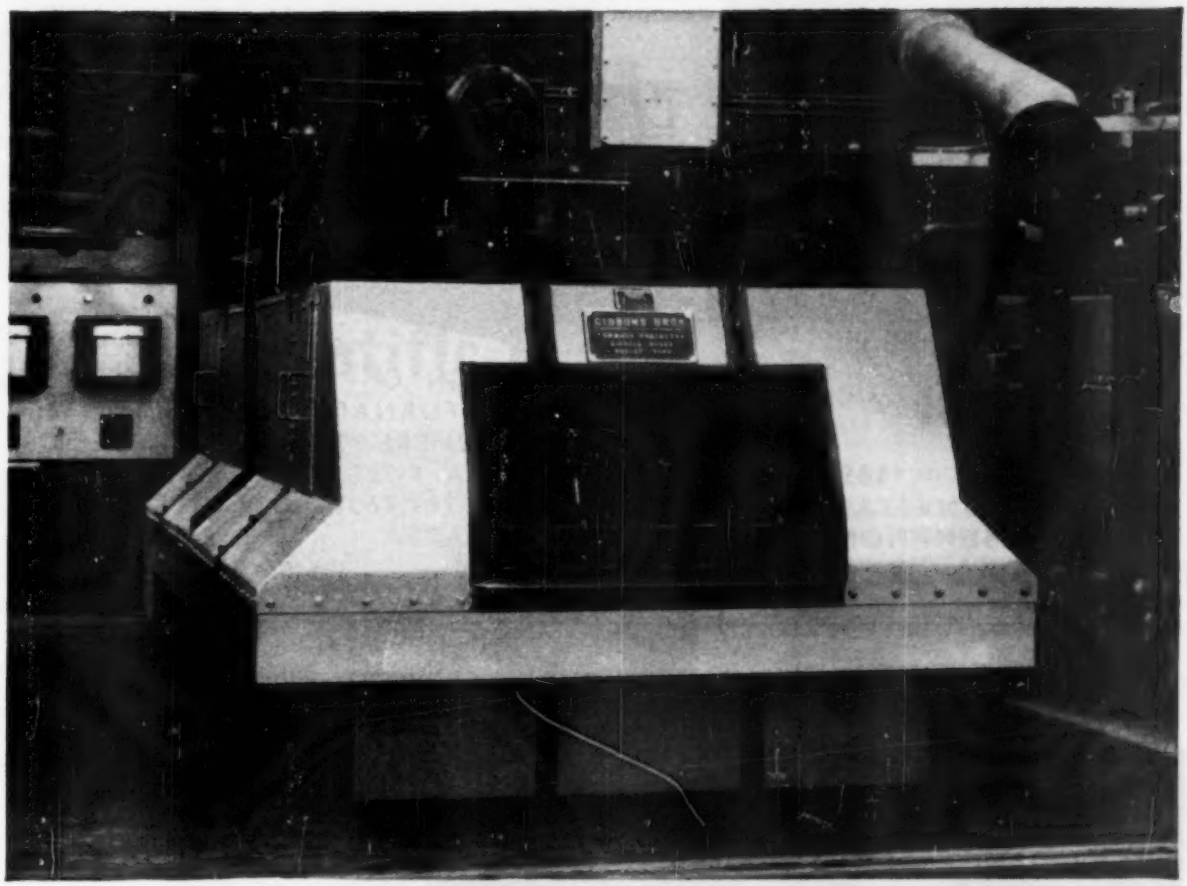

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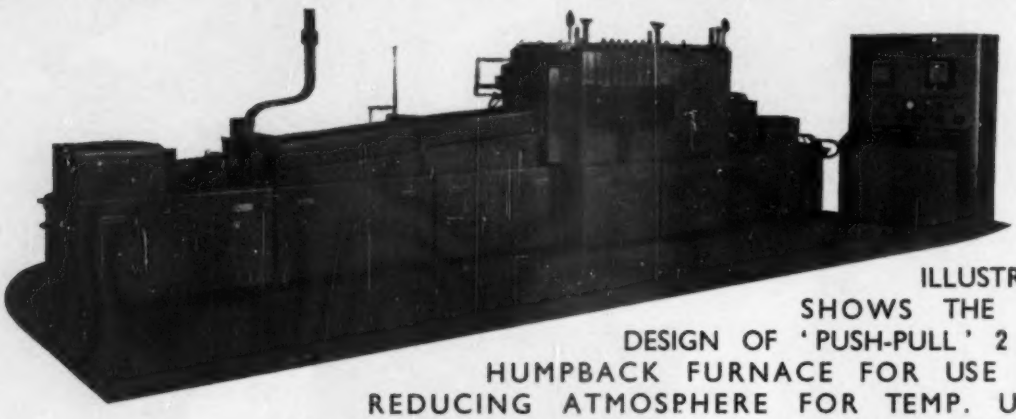

ILLUSTRATION SHOWS THE NEW DESIGN OF 'PUSH-PULL' 2 ZONE HUMPBACK FURNACE FOR USE WITH REDUCING ATMOSPHERE FOR TEMP. UP TO 1350°C. INCORPORATING A FULLY AUTOMATIC BOAT CONVEYANCE SYSTEM (Pat. No. 789,760) LOW HYDROGEN CONSUMPTION. 66 kWs 8" WIDE BOATS.

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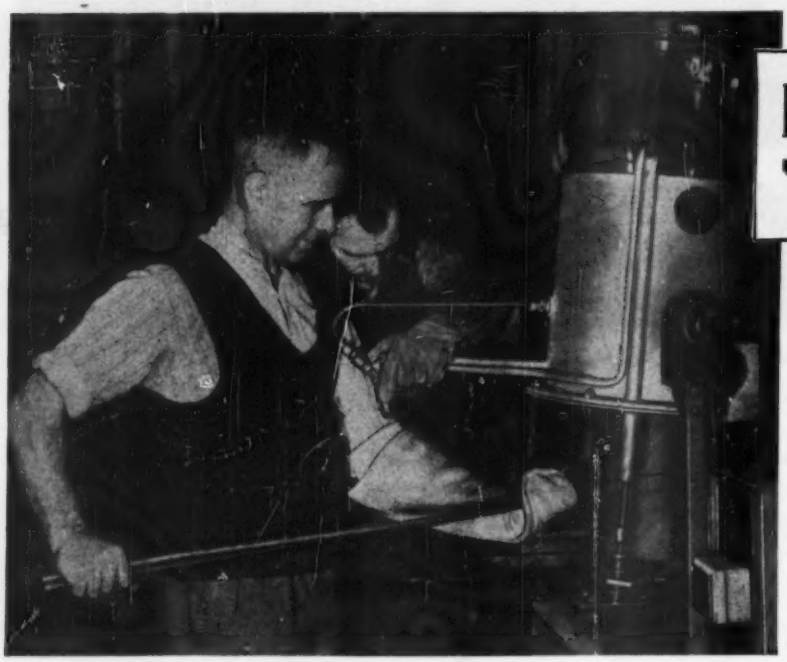

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permits the quantitative chemical analysis of volumes of material down to 1 micron cube. It is designed to cover the range of elements from uranium to titanium. With additional equipment—a proportional counter, amplifier and pulse height analyser—the range can be extended from titanium to aluminium.

In this micrograph each black dot represents an area of approximately 1 micron diameter studied by the x-ray micro-analyser at the surface of a bismuth copper aluminium alloy. Five separate phases occurring in the fusion of the alloy were identified.

Let us look into your problem

Experts of our Advisory Service can almost certainly help you with problems of scientific investigation in any of the fields mentioned below.

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X-RAY MICRO-ANALYSIS

Associated Electrical Industries Limited
INSTRUMENTATION DIVISION
Scientific Apparatus & X-Ray Dept.
Trafford Park, Manchester, 17

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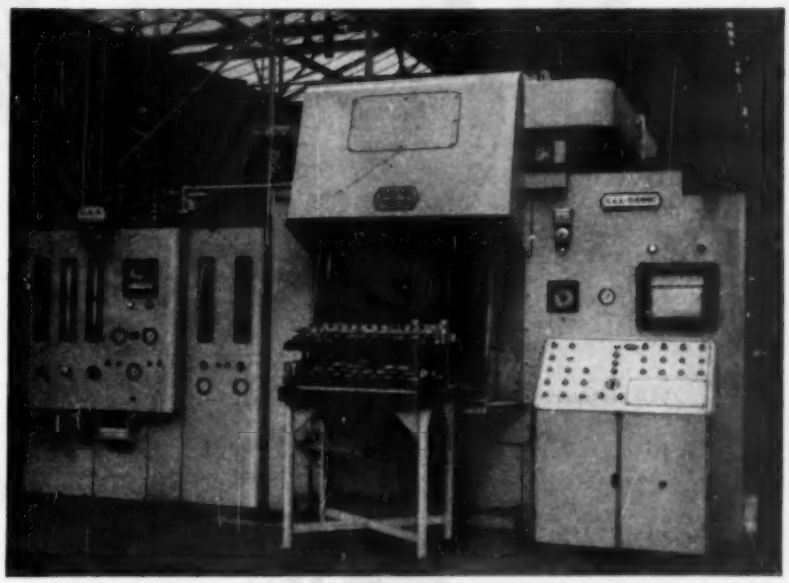
IN this modern general metals age of ours it seems a far cry to the days when the heat treatment of metals was considered to be a 'black art' and when the closely guarded secrets of the swordmakers and workers in precious metals were handed down from father to son. Today we recognise the value of the comparatively new technology of metallurgy and realise the benefits our civilization receives from the new metallic alloys and from the new plants and methods of processing these alloys which have been developed during the last few decades.

The type of plant we have in mind includes such items as the new heat treatment furnace which the West Midlands Gas Board recently has had installed in its Heat Treatment Service establishment located at Adderley Street, Birmingham 9. This establishment was brought into being by the Birmingham Gas Department more than 40 years ago and the plant has been continually brought up to date. The experience of the metallurgical staff of the 'service' is considerable and this is reflected in the quality of the supervision given to all the heat treatment processes carried out at Adderley Street, as well as in the advice given to consumers concerning the use of gas fired plant. This new item of plant, one of the first of its kind to be installed in the Midlands, is an atmosphere controlled batch-type unit, capable of accepting a total load measuring 3 ft. 0 in. wide, 2 ft. 0 in. deep and 1 ft. 6 in. high, and operating up to temperatures of 950° C. The furnace itself comprises two separate chambers, a hot zone, heated by recuperative gas fired nickel-chrome radiant tubes, placed above and below the work chamber; and a water jacketed discharge vestibule. An oil quench tank is incorporated below this vestibule and both the vestibule door and the inner furnace door are power operated.

Controlled atmospheres, suitable for a wide variety of treatments including clean hardening and annealing, gas carburising and carbonitriding, are supplied from an endothermic generator forming part of the plant. This generator is fired by towns gas but uses propane gas and air for the production of the endothermic gas. Both propane and ammonia enrichment are provided, for use when gas carburising or carbonitriding, and it is possible to vary the 'dew point' of the atmosphere gas in order to provide clean heat treatment of steels over a wide range of specifications.



This Gas-fired furnace of new design for gas carburising and clean heat treatment in controlled atmospheres is a working exhibit at the Board's Heat Treatment Service establishment.

The furnace is operated from a control panel and desk which provides automatic furnace temperature recording control, atmosphere control and push button control of all the power operations attendant upon the charging, discharging and quenching of the furnace load, which thus become automatic operations, each action being indicated by signal lights on the panel. Vertical flow gauges and dial gauges incorporated in the panel complete the instrumentation of the plant, and the panel thus gives the operator an immediate picture of the stage of the process and the state of the plant at any given time.

In order fully to demonstrate this plant to prospective purchasers it is of course necessary to operate it on a commercial heat treatment shop basis and the Board's Heat Treatment Service is open to receive orders for the gas carburising of such items as crown wheels and pinions, gears, cams and cycle components, clean annealing, hardening, and tempering of special die blocks, machined parts and similar items. All this work would be carried out to the requirements of the client concerned, would be supervised by qualified metallurgists, and when necessary would conform to the dictates of any inspection approval.

Industrialists, metallurgists and plant engineers are invited to inspect any of the items of plant at Adderley Street either with a view to installing similar plant at their own works or for the purpose of assessing the usefulness to their own organization of the commercial heat treatment facilities provided by the 'Service'.

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METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

January, 1960 Vol. LXI. No. 363

Steel Prospects

SINCE the end of the war, steelmaking capacity in the United Kingdom has increased steadily from a figure of 14 million ingot tons in 1946 to 24½ million tons in 1959. This was accompanied—or should it be led—by a steadily increasing demand which continued until late in 1957, when a recession began which brought the iron and steel industry's output down to some 70% of capacity by the end of 1958—the first significant downward movement in production for twenty years. The recession in steel demand was world-wide, but varied considerably in extent. Of the three main contributory elements in this country—a decline in home consumption, a lowering of steel consumers' stocks, and a fall in direct exports of steel—changes in consumers' stocks were the most important, and it is estimated that in the eighteen months from March 1958 to September 1959 consumers and merchants reduced their holdings by 1·6 million ingot tons. The experience of the post-war years has shown that during a period of industrial boom and high steel demand, consumers add disproportionately to their stocks, whereas in a period of relatively low industrial activity and easy steel supplies they reduce their stocks. Thus, instead of stock-building providing a reservoir from which industry can keep going when supplies of raw materials are tight, it seems to be an important factor in accentuating the peaks and dips in the curve of steel demand.

Although an appreciable proportion of the steel industry's capacity has been idle during the last two or three years, this inactivity was not spread uniformly throughout the industry, varying according to the fortunes of the industries they served. For example, the motor vehicle, household durables, metal container and electrical machinery industries were fully employed most of the time, with the result that producers of sheet and tinplate were little affected by the recession. On the other hand, shipbuilders, the coal mines and the railways reduced their intake of steel, and this had severe repercussions in steelworks producing heavy plates, rails, colliery arches, heavy sections and tyres, wheels and axles. The producers of re-rolled products and tubes also suffered from low demand in the building, engineering and oil industries.

In the January issue of the British Iron and Steel Federation quarterly, *Steel Review*, there is a survey of prospects for steel in the coming year in which is stressed the difficulty of adapting the industry's production pattern to rapid changes in the pattern of steel demand, due to the highly specialised character and high cost of the equipment required, particularly for the production of wide strip. In a modern steelworks up to £15,000 worth of equipment has to be provided for each employee —a total of £150 million for a large integrated strip plant employing 10,000 men. Moreover, it takes a long time to plan, build and bring into full operation such a large unit—much longer than it takes the industry's consumers to expand their capacity. Finally, some sectors of steel demand are particularly subject to short-term fluctuations initiated by Government fiscal measures, changes in public taste or habit, and the stockpiling policies of consumers.

The direct export of steel during the latter half of 1959 has been affected by the American steel strike and the temporary boost from this cause is unlikely to operate in 1960. Nevertheless, the Federation believes that—allowing for the more favourable world economic climate—steel exports for the year 1960 may show a moderate recovery from the 1959 level of 3½ million tons.

As far as home demand is concerned, consumer durables will probably continue to do well and requirements of sheet and strip are likely to be high. Due to an unexpectedly swift boom in cars, rising sales of household goods and electrical machinery, and a change from hot rolled to cold rolled sheet for the manufacture of certain products, there have been shortages of cold-reduced sheet, despite the production increase of 13% compared with 1958. A further rise of 20% in 1960, expansion at existing strip mills, and the construction of two new mills at Newport and Ravenscraig, work on which is being accelerated, are expected to reduce still further the import of sheets and, ultimately, meet the likely demand for this class of product.

The prospects in the investment field, which accounts for the major part of steel consumption, are of a continuing increase in the public sector—though with a declining steel intensity—but of a small fall in investment by private manufacturers and distributors, partly offset by increased outlays in other private industries (agriculture, building, etc.). There is likely to be some recovery in indirect exports, in the Federation's view, and although there may still be some margin of capacity in certain heavy steel products, as a result of continued slackness of demand from railways, coal mines and shipbuilders, total home consumption (as distinct from purchases) of steel in 1960 may well rise by 1–1½ million ingot tons above the 1959 level of just under 18 million tons. It is also expected that circumstances will favour an increase in consumers' and merchants' stocks to a level above that at the beginning of 1959. Taken all in all, crude steel consumption could rise by about 4 million tons above the 1959 level, to some 24 million tons, representing a utilisation of more than 90–94% of capacity.

Substantial increases in output in 1960 will be available from plant installed in 1959 and from the starting up of new plant, notably the new integrated South Durham development, which includes a blast furnace, steel melting shop, slabbing mill and 4-high plate mill. Other new plant commissioned in 1960 will increase capacity in ironmaking, in steelmaking, in plate, billet and strip rolling, and in tube making.

Plans for later years are also well advanced, the two

outstanding projects, due to start up in 1962, being the new strip mills at Newport and Ravenscraig. Other important features of the programme include the installation of two 80-ton rotor furnaces and a continuous billet mill at Richard Thomas and Baldwins' Redbourne Works, and a new melting shop at Consett in 1961, English Steel Corporation's new steelworks at Tinsley Park, and Steel, Peech and Tozer's new electric melting shop to replace an existing cold metal shop. Detailed assessments of likely steel requirements in 1965 are being prepared, and will form the basis for the companies' further development plans, but it is clear from schemes already submitted that by 1965 the industry's crude steel capacity will be in excess of 30 million tons a year, quite apart from any increase in productivity resulting from the wider application of tonnage oxygen in existing processes and the increasing adoption of new processes based on oxygen.

The fact that in the 1960's there is likely to be ample capacity available for the production of steel makes it even more important to predict as reliably as possible the pattern of steel demand in terms of finished steel products. The prospects of a more comprehensive free trade association with other Western European countries enhances the difficulty of foreseeing the structure of orders placed with British producers. Such an association would, the Federation believes, ensure greater flexibility of supply and, it is hoped, an expanding market both for steel and for the many manufactured goods of which steel forms the main base.

Meeting Diary

22nd February

Institution of Plant Engineers, Birmingham Branch. "Modern Welding Methods," by R. T. ANDREWS. Hotel Leofric, Coventry. 7.30 p.m.

23rd February

Institution of Plant Engineers, South Wales Branch. "Metal Stitching," by N. TINWELL. South Wales Engineers' Institute, Park Place, Cardiff. 7.30 p.m.

Sheffield Metallurgical Association. "The Importance and Determination of Trace Elements in Steel," by L. KIDMAN. B.I.S.R.A. Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

24th February

Institute of British Foundrymen, London Branch. "Modern British Bathmaking Practice," by G. R. WEBSTER. Illustrated by film. Constitutional Club. Northumberland Avenue, London, W.C.2. 7.30 p.m.

Manchester Metallurgical Society. "The Presentation of Metallurgical Information, by DR. J. W. JENKIN. Manchester Room, Central Library, St. Peter's Square, Manchester. 6.30 p.m.

25th February

North East Metallurgical Society. "Copper and Copper Alloys in Modern Technology." Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough. 7.30 p.m.

Southampton Metallurgical Society. "Strain Ageing of Steel," by T. R. S. WILLIAMS. Engineering Block, Southampton University. 7.15 p.m.

1st March

Institute of Metals, Oxford Local Section. Junior Member's Evening. "Developments in Mechanical Testing Methods": (*a*) "Hot Hardness Testing", by O. P. HARTREE; (*b*) "The Mechanical Testing of α-active Materials", by P. M. FRENCH; (*c*) "The Mechanical Testing of γ-active Materials", by J. E. BAINBRIDGE. Cadena Cafe, Cornmarket Street, Oxford. 7 p.m.

Institute of Metals, South Wales Local Section. Annual General Meeting, followed by "Porosity in Sintered Materials", by PROF. R. HIGGINS. Metallurgy Department University College, Singleton Park, Swansea. 6.30 p.m.

Sheffield Metallurgical Association. "Cold Forging and Extrusion of Steel", by DR. J. B. HAWKYARD and N. S. ANGUS. **Joint Meeting with the Sheffield Society of Engineers and Metallurgists.** B.I.S.R.A. Laboratories. Hoyle Street, Sheffield 3. 7 p.m.

3rd March

Institute of Metals, Birmingham Local Section. "The Effects of Irradiation on Reactor Materials," by DR. H. M. FINNISTON. College of Technology, Gosta Green, Birmingham. 6.30 p.m.

Institute of Metals, London Local Section. "Patent Law", by C. E. EVERY. 17. Belgrave Square, London, S.W.1. 6.30 p.m.

Liverpool Metallurgical Society. "Semi-Conductors", by R. P. CHASMAR. **Joint Meeting with the Institute of Metals.** Library, Dept. of Metallurgy of the University of Liverpool, 146, Brownlow Hill, Liverpool, 3. 7 p.m.

5th March

Liverpool Metallurgical Society. Seventh Annual Conversazione. University Club.

7th March

Sheffield Metallurgical Association. "Bonding Clays: Recent Work and Ideas", by PROF. A. L. ROBERTS. **Joint Meeting with the Sheffield Branch of the Institute of British Foundrymen.** Sheffield College of Commerce and Technology, Pond Street. 7 p.m.

Society of Chemical Industry, Corrosion Group. "Corrosion Problems of High Temperature Pressurised Water Reactors", by J. N. WANKLYN. **Joint Meeting with Yorkshire Section.** Grand Hotel, Sheffield. 7 p.m.

9th March

Institute of Welding, South London Branch. "The Future of Gas Shielded Welding," by A. A. SMITH. 54, Princes Gate, London, S.W.7. 7.30 p.m.

Manchester Metallurgical Society. "Metallurgical Aspects of Fuel Elements for Nuclear Reactors", by DR. H. M. FINNISTON. Manchester Room, Central Library, Manchester. 6.30 p.m.

10th March

East Midlands Metallurgical Society. "Oxygen in Steelmaking". Central Electricity Authority Showrooms, Arkwright Street, Nottingham. 7.30 p.m.

Institute of Fuel, Midland Section. "The Work of B.C.U.R.A.", by DR. D. T. A. TOWNEND. Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, 2. 6.30 p.m.

Leeds Metallurgical Society. "Unpopular Methods for Establishing Equilibrium Diagrams", by DR. H. W. RAYSON. Arrangements to be announced.

14th March

Institution of Plant Engineers, Merseyside and North Wales Branch. Annual General Meeting, followed by a film "Tubular Engineering". Exchange Hotel, Liverpool. 7.15 p.m.

Sheffield Metallurgical Association. An all-day Symposium on Hot Extrusion of Steels, held jointly with the **Sheffield Society of Engineers and Metallurgists.** Details to be announced.

15th March

Institute of Metals, South Wales Local Section. "Atomic Structure and the Properties of Metals", by PROF. N. F. MOTT. Metallurgy Department, University College, Singleton Park, Swansea. 6.30 p.m.

Sheffield Metallurgical Association. Refractories Group Lecture. Title to be announced. B.I.S.R.A. Laboratories, Hoyle Street, Sheffield, 3. 7.30 p.m.

The Treatment of Trade Effluent at Wilmot-Breeden, Ltd., Bridgwater

By K. G. Robinson, B.Sc.*

This article describes the construction and operation of a compact effluent treatment plant at a works situated in a rural area where very tight limits on effluent quality were imposed. In view of the potential variety in both quantity and type of effluent every effort was made to install plant with the maximum flexibility. Recently the value of this has been appreciated in that changing products have led to a greater output of trade effluent than was originally anticipated.

IN planning the layout of the Wilmot-Breeden factory at Bridgwater, it was realised at an early stage that the disposal of trade effluent would be of considerable importance. This particular feature was aggravated by the fact that the factory is situated in a rural area where this type of trade effluent is a relatively isolated occurrence. Since the treated effluent finally discharges into the River Parrett, which is frequented by salmon and trout, the Somerset River Board is also involved. These factors resulted in the imposition of very tight limits which are almost unique for the quality of the final effluent discharged into the sewer.

It was anticipated that provision would have to be made for the treatment of the following types of effluent in quantities which would inevitably vary with the development of a new factory :

Acid Effluent

(1) Effluent from phosphating plant.

(2) Swills from anodising equipment (both chromic acid and sulphuric acid).

(3) Swills from a variety of metal pickling operations.

(4) Effluent from chromium plating plant.

(5) Occasional batches of strong acid effluent resulting from the emptying of plating and pickling vats.

Alkaline Effluent

(1) Swills from degreasing and cleaning plant.

(2) Cyanide-bearing swills from various plating operations.

(3) Occasional batches of strong alkaline solutions, including cyanide-bearing effluent, during the dumping of work vats.

Although it was appreciated that there would be fluctuations in the type and degree of contamination of the effluent, it was decided that a continuous type treatment plant should be installed, as it was felt that the laboratory control envisaged together with some instrumentation would ensure a treated effluent of uniform composition. The relative compactness of a continuous plant also meant that it could be confined to an available site which is adjacent to the part of the factory where most of the effluent originates. The diagrammatic layout of the final installation is shown in Fig. 1 and a general view is to be seen in Fig. 2.

Basically, the plant consists of a number of suitably interconnected pit-type reaction and settling tanks cast in reinforced concrete and lined with chemically resistant brickwork. Within these chambers the chemicals required for the treatment of the effluent are added in controlled quantities at the appropriate stages of treatment. By this means, much of the contamination is rendered insoluble and in the final stages of treatment precipitates in the settling tanks as a sludge which is pumped out at intervals and dumped. Since all the tanks are below ground level, the flow of liquid to the plant and within the plant is arranged by gravity feed, thus obviating the need for mechanical pumps in the main operation of the plant. This feature has the added advantage that in the event of a local power failure the main plant would still operate at a reduced rate. This latter feature is due to the fact that in order to expedite mixing of the reacting chemicals all the primary reaction chambers are fitted with electrically driven stirrers. Finally, duplicate settling tanks are provided in parallel, so that they may be de-sludged in turn without necessarily stopping the operation of the plant as a whole.

For dealing with concentrated effluent which may arise occasionally with the dumping of plating, pickling or processing solutions, two independent batch treatment tanks with mechanical stirrers are provided. Each tank will accommodate approximately 1,000 gal. One tank is used for the treatment of concentrated alkaline and cyanide effluent and the other for strong acids. After treatment, the effluent from either of these two tanks is discharged by an electric pump into a suitable point in the main effluent plant, so that the sludge may settle out in the settling tanks.

The following description of the sequence of processing operations should be read in conjunction with Fig. 1. Starting at the inlet end of the plant there are the two batch treatment tanks which have been described above, and which have no direct connection with the continuous plant except that the batch treated effluent is ultimately pumped into the final stages of the main plant to allow precipitation of the sludge in the settling tanks. This system of separate treatment of concentrated effluent was chosen because the sudden introduction of very strong solutions into the continuous plant would obviously upset its balance. This is due to the fact that although certain treatment chemicals are introduced via automatically operated valves, others which do not readily lend themselves to economic automatic control, or which are themselves innocuous in excess, are introduced via manually controlled valves. The batch treatment tank

* Chief Metallurgist, Wilmot-Breeden, Ltd., Bridgwater.

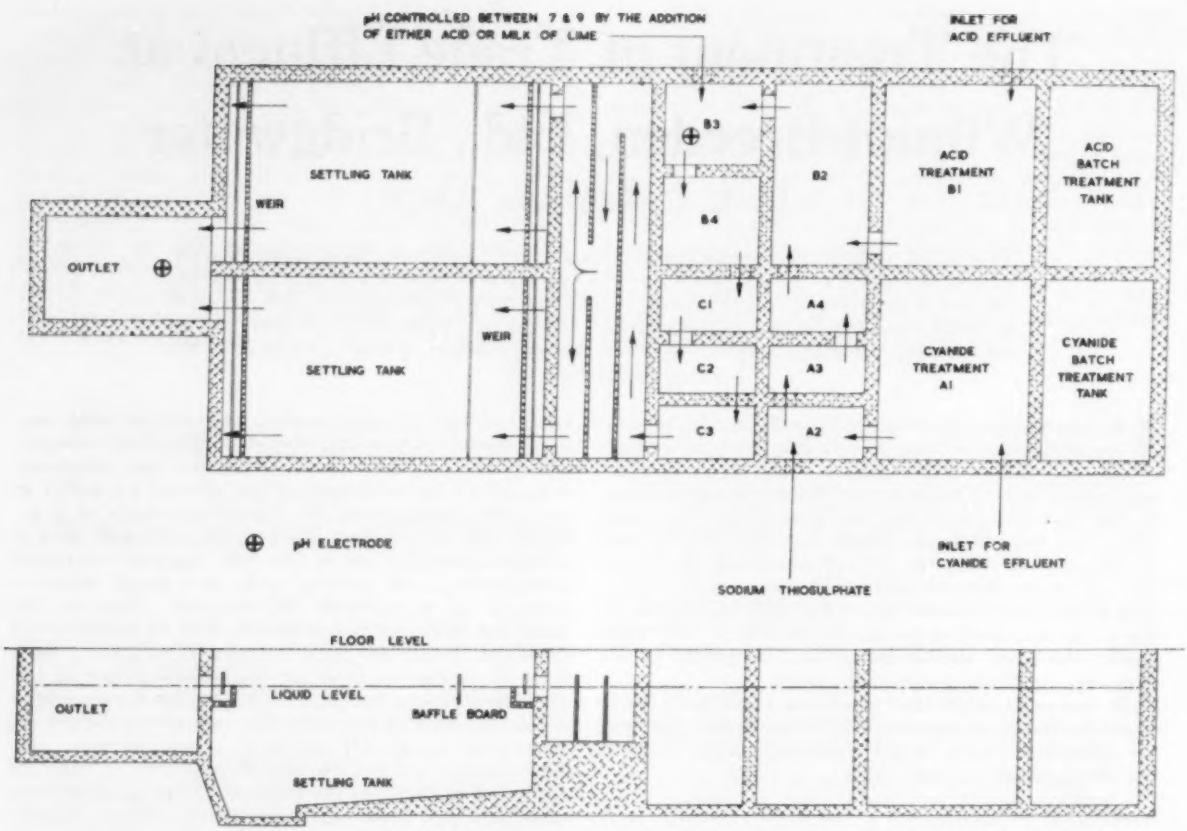

Fig. 1.—Diagrammatic layout of effluent treatment plant.

on the cyanide side of the plant is connected by suitable pipelines to the chemicals necessary for the destruction of the cyanide, namely caustic soda and sodium hypochlorite. The former is added as necessary to raise the *p*H to 10 or above, when complete and rapid destruction of the cyanide follows during chlorination with sodium hypochlorite. At lower *p*H levels the destruction of the cyanide is neither so rapid nor complete. The mixing rate is increased by an electrically driven stirrer. On completion of the reaction the treated effluent is pumped slowly into the main plant, adjacent to the sodium thiosulphate inlet, where the excess chlorine is neutralised by a temporary increase in the flow of sodium thiosulphate. Similarly, on the acid side of the plant ferrous sulphate and milk of lime are piped into the acid batch treatment tank. A preliminary addition of ferrous sulphate is only necessary if chromic acid is present, and then in proportions sufficient to reduce the chromic acid to the trivalent state. The milk of lime is added to neutralise the acid content and to maintain the *p*H at such a level that precipitation of the metal salts will occur. Finally, the treated effluent is pumped into the main plant prior to the settling tanks. As both of these batch treatment tanks are only included for dealing with occasional batches of strong effluent, the various chemicals enter via manually controlled valves. These latter additions are made under laboratory supervision.

Following on from the two batch treatment tanks there is the main continuous plant, which initially operates in two parallel parts. In the first reaction tank marked *A*1 in Fig. 1, the combined incoming alkaline and cyanide effluent is maintained at a minimum *p*H of 10, if necessary by the further controlled addition of caustic soda solution. As mentioned earlier, in order to attain the desired rate and completeness of destruction of the cyanide content by chlorination, it is necessary to maintain the *p*H at a minimum of 10. Chlorine in excess of the theoretical requirements is added, as this excess also promotes the effectiveness of the reaction as well as dealing with small fluctuations in cyanide content. Both the sodium hypochlorite and the caustic soda additions are controlled by manually operated calibrated valves. Regular laboratory analyses during the course of the day decide the setting of these valves. Short time fluctuations in the degree of contamination of the effluent entering the plant are levelled out by the fact that the reaction chamber has a capacity of 1,750 gal., so that with a maximum throughput of cyanide effluent of the order of 4,000 gal./hr. there is adequate retention time. The mixing is further assisted by an electrically driven stirrer unit. On leaving this chamber the addition of sodium thiosulphate under manual control is made to destroy the excess chlorine content. Further and final mixing is attained in chambers identified in Fig. 1 as *A*2, *A*3, and *A*4. It will be seen from the diagrammatic layout that this final mixing is further

promoted by the method of inter-connecting these tanks. Chamber *A*2 is connected to *A*3 by an underpass in the bottom of the dividing wall so that the effluent is forced down through *A*2 and rises in *A*3. Next, the rising effluent passes into chamber *A*4 via a weir at liquid level in the dividing wall, and finally leaves *A*4 again by an underpass. At this point it joins the stream of partly treated acid-bearing effluent. Practical operating experience has shown that the method of cyanide treatment just described gives very satisfactory results. The treatment of the acid-bearing effluent prior to joining the treated cyanide effluent will now be described.

The incoming mixed acidic effluent enters the primary reaction tank *B*1, where rapid mixing of the effluent is promoted by an electric stirrer. Ferrous sulphate solution is added under manual control, as decided by routine chemical analysis, to reduce to the trivalent state any chromic acid which may be present. This reaction chamber also has a capacity of 1,750 gal., which gives adequate retention time for a throughput of up to 4,000 gal./hr. Following this stage the acid effluent joins with the cyanide-free alkaline effluent when the one chemically in excess neutralises the other, thus economising in treatment chemicals. The reaction occurs in chamber *B*2 which has a capacity of 1,000 gal. and where mixing is assisted by mechanical means. The combined effluent enters chamber *B*3 where the *p*H is automatically adjusted to between 7 and 9 by the controlled addition of either acid or milk of lime. Mechanical stirring is included. A *p*H electrode immersed in this chamber senses any change in *p*H and transmits a signal through a D.C. amplifier. This amplified signal is fed to an electro-pneumatic converter, the resulting pneumatic output then operating a *p*H recorder-controller. This latter instrument operates pneumatic valves which switch in either the acid or milk of lime supply to chamber *B*3. Experience has shown that careful relative positioning of the *p*H electrode, the stirrer and the inlets for the treatment chemicals is necessary to attain adequate smooth control. If these positions are not correct, hunting of the system will result, the over correction also leading to wastage of chemicals. Finally, the treated effluent passes via alternate weirs and underpasses through a series of reaction chambers identified as *B*4, *C*1, *C*2 and *C*3.

The neutralised effluent, together with the precipitated metal salts is conveyed by channels to two settling tanks each of 4,000 gal. capacity which normally operate in parallel. Provision is made by suitable penstocks for isolating either of these tanks for repair or cleaning. Normally the sludge is removed as necessary at the weekends.

In order to promote the quiet and uniform flow necessary for adequate settlement, the neutralised effluent and suspended precipitate enter the settling tanks along the full length of a weir extending over the width of each settling tank. This weir is built at virtually the normal liquid level in the settling tank to avoid any appreciable fall, which causes unnecessary agitation of liquid in the settling tank. At the output end of each settling tank there is a similar full length weir arranged slightly below the normal static liquid level. By this means the overflow is spread uniformly across the full width of the settling tank and is confined to the clarified surface layers. In order to prevent the incoming effluent with the suspended solid matter channelling straight across the surface layers of the liquid in the settling tanks it has been necessary to fit baffle boards at strategic points. Initially considerable difficulty was experienced with poor settling due to this factor. It was found that if baffle boards were fitted across the full width of the settling tanks dipping about 18 in. below the surface of the liquid the flow could be deflected downwards. Obviously the degree of deflection was largely dependent on the positioning and depth of these boards. Experiments showed that the disposition of these boards together with the level of the weirs was most critical, and considerable investigation and experiment was necessary to find the best combination. For instance, excessive deflection tended to force the treated effluent too far down into the settling tank and thereby disturb the surface layers of the settled sludge, more especially towards the time for cleaning out of the plant. At the present time these conditions have to be closely watched, since the ratio of throughput to settling tank volume is on the high side, due to the greatly increased demand now being made on the effluent plant. However, by close observation of the above described conditions, very satisfactory settling is being attained.

Fig. 2.—A general view of the plant.

Finally the clarified effluent passes into an outlet chamber which connects with the sewer. In this outlet chamber there are the electrode for a *p*H recorder and the measuring element for a recording flowmeter. In addition to recording continuously the *p*H of the final effluent, the *p*H recorder also incorporates contacts for an audible warning device which indicates any deviation from the set limits for *p*H.

As mentioned previously, the unusual local conditions have caused limits to be set, particularly with respect to cyanide and *p*H, which are much tighter than those normally accepted. Despite these tight limits the plant has functioned satisfactorily and produced an acceptable effluent during the time since commissioning in the latter part of 1957.

Mobile Low-Temperature Apparatus

By S. S. Chang,* B.Sc., Ph.D., A.M.I.Mech.E., A.M.I.Prod.E.,
and J. D. Isdale*

Mobile equipment designed to maintain a test specimen at a constant sub-zero temperature for periods up to 1½ hours is described. To date a specimen temperature of −80° C. has been reached for a few minutes and temperatures down to −39° C. have been maintained for the prescribed period. Further work is in progress in order to reach lower temperatures.

IN experiments on the effects of strain rate and temperature on the tensile properties of materials, it is frequently necessary to maintain the specimen at a constant temperature in the range −196° to 200° C. for periods of up to 1½ hours. For the high temperatures the conventional method is to heat a water or oil bath by an immersion heater with a regulated voltage supply. This is satisfactory for maintaining any temperature between room temperature and 200° C. However, on the low-temperature side, only a few fixed temperatures, such as the melting point of ice, the sublimating point of solid carbon dioxide and the boiling point of liquid nitrogen can be readily obtained and maintained over a long period. To carry out tests of long duration at temperatures other than these it is necessary to consider other methods.

The object of this work was to design apparatus capable of maintaining the test specimen at a constant sub-normal temperature, as low as possible, over a period of up to 1½ hours. The apparatus was required to be mobile so that it could be used in conjunction with different testing machines in the laboratory.

* Plasticity Division, National Engineering Laboratory, East Kilbride, Glasgow.

Construction

The principle underlying the design of the apparatus is to boil organic liquids at a controlled sub-atmospheric pressure to obtain any desired temperature between the triple point and the boiling point at atmospheric presssure. A diagram of the apparatus is shown in Fig. 1. For mobility the whole unit is mounted on a trolley 6 × 3 × 3 ft. high (Fig. 2).

The organic liquid (refrigerant), *T* in Fig. 1, is contained in a large Dewar flask *S* seated in a well-insulated wooden box *U*. The flask is closed at the top by a conical metal cover *P*, which is held to it by a strong rubber seal *O*. The openings on the metal cover are for the outlet of refrigerant vapour *L*, for refilling the flask with the refrigerant *Q*, for secondary air leak through a needle valve *H*, for coarse measurement of pressure by manometer *G*, and for fine measurement of pressure by vacuum gauge *E*. *F* is a quick air leak for emergency use, which also allows for the entry of a thermocouple to measure the temperature inside the flask, if required; however, the temperature is normally measured directly on the tensile specimen. The metal cover is insulated

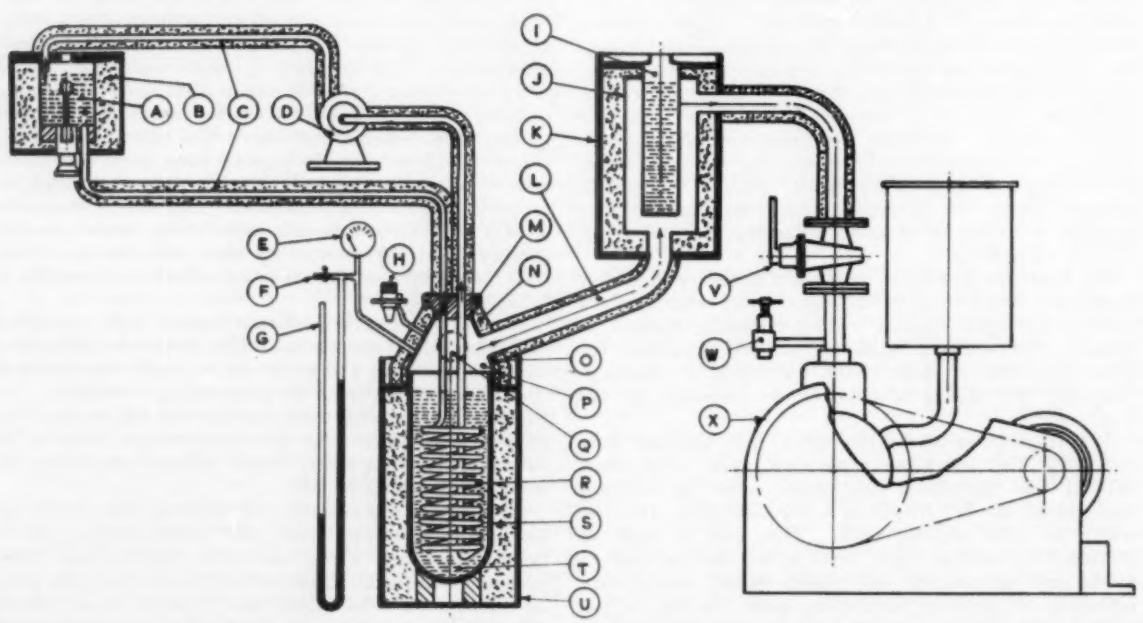

Fig. 1.—Diagrammatic representation of mobile low-temperature apparatus.

from the atmosphere by an asbestos compound *N*. The hole in the top of the metal cover is closed by a tightly fitting rubber bung *M*, through which pass the ends of a copper tube coil *R* immersed in the refrigerant. The ends of the coil are connected by insulated copper tubing to an insulated chamber *B*, containing the tensile specimen. The coolant *A* is pumped through this circuit by a centrifugal pump *D*. An insulated pipe *L* passes from the Dewar flask through a reflux condenser *J* to a vacuum pump *X*. The reflux condenser, made of copper sheeting, is enclosed in an insulated wooden box *K*. The refrigerant vapour entering *J*, under the suction of the vacuum pump, is condensed by the condensing agent (liquid nitrogen or solid CO_2—acetone mixture) contained in the cooling chamber *I* which is open at the top to allow for refilling. The condensed refrigerant then flows under gravity back to the Dewar flask, thus minimising the loss of refrigerant vapour to the atmosphere.

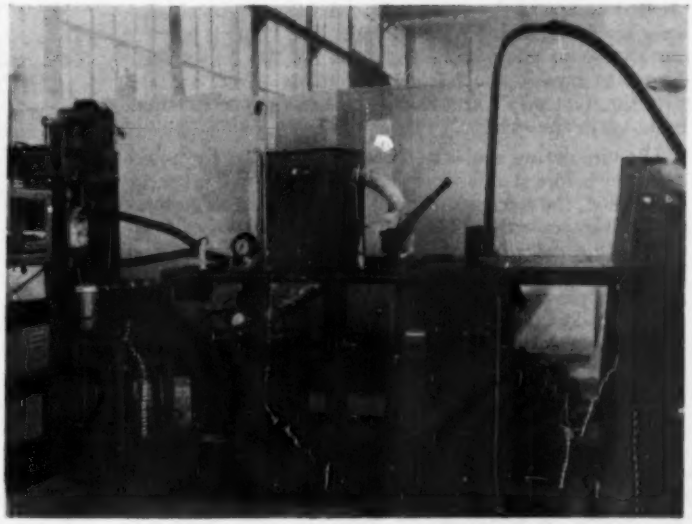

Fig. 2.—Mobile low temperature apparatus.

The heat cycle of the system is as follows. The coolant *A* absorbs heat from the specimen and machine parts and transfers it to the refrigerant *T* in the Dewar flask, causing boiling. The resultant refrigerant vapour then conveys the heat to the condensing agent *I* in the reflux condenser, condenses and flows back to the flask. The condensing agent is allowed to evaporate, and thus the required temperature is maintained in the system at its expense. The temperature of the boiling refrigerant remains constant for a given pressure. A main valve *V*, for opening and closing the whole circuit, and two needle valves, *W* and *H*, for primary and secondary air leaks, respectively, are used to adjust the pressure and hence the temperature required in each test.

The design of the apparatus is very similar to that of the N.P.L.[1] However, in the N.P.L. design no facility is provided for the condensed refrigerant to flow back to the Dewar flask. Instead of the reflux condenser, the N.P.L. design makes use of two "liquid air traps" which are connected in parallel to trap the vapour, one being used at a time. When one of them is filled with condensed refrigerant it is disconnected from the circuit and the other connected for use. In the present design, the condensed refrigerant flows continuously back to the flask, ensuring a steady condition for a long period without losing much refrigerant. This method of conserving the refrigerant is obviously important in long duration tests and in tests where an expensive refrigerant is used.

Operation

(1) *For a Refrigerant whose Boiling Point at Atmospheric Pressure is Higher than Room Temperature*

The Dewar flask is filled with a suitable refrigerant to a level well above the top of the copper coil, the specimen chamber *B* is filled with coolant *A*, and the reflux condenser is charged with a suitable condensing agent. After allowing a short time for the initial cooling of the condenser, the circulating and the vacuum pumps are started with the main valve *V* closed and the primary leak valve *W* open. With *W* open, the system will not have any undesirable sudden change of pressure when the main valve *V*, which gives rather coarse adjustment, is opened to start operation. The Dewar flask is then sealed by replacing the refill lid *Q* and by closing the secondary air leak valve *H*.

The main valve *V* is then slightly opened to allow a small amount of the warm vapour to enter the reflux condenser, thus lowering the pressure in the Dewar flask. This vapour causes accelerated boiling of the condensing agent in *I*. The pressure in the flask is measured by the manometer *G* and the specimen temperature is measured by a thermocouple. The primary air leak *W* is then gradually closed to allow the suction of the vacuum pump to produce a further drop in pressure and a consequent drop in temperature in the Dewar flask *S*. The two valves are operated very slowly so as to allow time for the vapour to condense and, therefore, to prevent its loss through the pump. The loss of refrigerant can normally be detected by the vigorous boiling of the condensing agent *I* and the smell of the vapour in the exhaust gas of the pump.

If the temperature reached is not sufficiently low, the primary leak *W* is fully opened again and the main valve *V* opened a little further. This is again followed by gradual closure of the leak. This procedure can be repeated until a temperature slightly lower than the required level is reached. The final fine adjustment is then made by admitting air through the secondary leak *H* directly into the Dewar flask.

(2) *For a Refrigerant whose Boiling Point at Atmospheric Pressure is Lower than Room Temperature*

The reflux condenser is first of all charged with a suitable condensing agent and the Dewer flask precooled by liquid nitrogen or solid CO_2. With the main valve *V* and primary leak *W* open, the refrigerant, normally contained in a cylinder under pressure, is transferred into the Dewar flask through a narrow insulated pipe at *Q*. The points where the pipe leaves the cylinder and where it enters the flask are sealed to

prevent escape of the refrigerant. A union and a rubber bung are found suitable for sealing. The filling is carried out slowly to allow sufficient time for the reflux condenser to liquefy the refrigerant boiling-off on contact with the relatively warm flask. This ensures no pressure build-up in the system.

The circulating coolant *A* is also pre-cooled by liquid nitrogen before it fills the system. If it is not properly pre-cooled, the refrigerant will boil vigorously on circulation of the coolant. This will cause a build-up of pressure with a risk of blowing off the metal cover from the Dewar flask, which is designed to stand a vacuum, but not high pressure. The method of pre-cooling by dissolving solid CO_2 in the coolant was found to be unsatisfactory, since the CO_2 gas coming out of the solution caused an " air " block in the centrifugal pump.

When the system is filled with both the refrigerant and the coolant, the centrifugal pump and the vacuum pump are started and the pressure and temperature lowered as before.

After the test, the refrigerant is allowed to escape, as no facility is available to re-collect and store the vapour.

Tests

Two groups of tests were carried out, using refrigerants with boiling points higher and lower than room temperature, respectively. In the first group, isopentane was used both as the refrigerant and as the coolant, and the reflux condenser was cooled by solid CO_2—acetone solution. Following the procedure outlined in the previous section, the temperature measured on the tensile test specimen could be lowered to about −39° C., the lowest reached in this group, after about one hour. Table I shows the result of a typical test. It is seen that in this test −37° C. was reached after 1 hour 25 minutes. Temperature variation of less than 2° C. was noticed in the next 30 minutes, but it was reduced to less than 1° C. in the last 58 minutes. This temperature could be maintained much longer, if required, as the loss of the refrigerant was found to be only 6% after the test. Other tests in the first group showed that equal stability of temperature could also be obtained at intermediate temperatures between room temperature and −39° C. For instance, at a pressure of 95 mm. Hg, the mean temperature over a period of 1 hour 40 minutes was −13·25° C., with maximum variation of 0·25° C.

In the second group of tests, " Arcton 6 " (CCl_2F_2), which has a boiling point of −30° C. and a freezing point of −158° C., was used as the refrigerant. Isopentane was used as the coolant and the reflux condenser was filled with solid CO_2—acetone solution and liquid nitrogen in turn. When the solid CO_2—acetone solution was used a temperature of −57° C. was reached, and by using liquid nitrogen −80° C. was achieved. It was found that by using solid CO_2—acetone solution the reflux condenser was not adequate to cope with the quick evaporation of the refrigerant, and consequently the refrigerant was lost quickly. It was also found that by using liquid nitrogen as the condensing agent, the refrigerant was frozen in the reflux condenser, as the freezing point of Arcton 6 is higher than the boiling point of liquid nitrogen. This resulted in the blockage of the passage from the Dewar flask to the vacuum pump and the test had to be stopped until the frozen Arcton 6 was melted.

TABLE I.—TEST ON APPARATUS WITH ISOPENTANE AS COOLANT AND REFRIGERANT

Time (hr.-min.)	Absolute Pressure in Dewar Flask (mm. Hg.)	Temperature of Tensile Specimen (° C.)
0-00	760*	18†
1-25	15	−37
1-36	13·5	−35·5
1-45	13	−35·75
1-50	13	−36·25
1-55	11·5	−36·25
2-02	11·5	−38
2-10	11	−38
2-18	11	−39
2-27	11	−38·5
2-33	11	−38·25
2-40	11	−38·25
2-45	11	−38
3-00	11	−38

* Atmospheric pressure. † Room temperature.

Conclusions

A mobile low-temperature apparatus has been developed based on the principle of boiling organic liquids at controlled sub-atmospheric pressures. It is capable of providing a low-temperature bath around the tensile specimen for tests at different strain rates. In the preliminary tests carried out to date, the lowest temperature reached on the tensile specimen was −80° C., for a few minutes, and temperatures down to −39° C. were maintained constant within 1° C. over one and a half hours, a period sufficiently long for a tensile test to be carried out at the lowest strain rate investigated. Further development is to be carried out in order to reach lower temperatures.

Acknowledgment

The work described has been carried out in the Plasticity Division, National Engineering Laboratory of the Department of Scientific and Industrial Research. This paper is published by permission of the Director. The authors are indebted to Messrs. W. P. Rees, B. E. Hopkins and H. R. Tipler, Metallurgy Division, National Physical Laboratory, for making available details of the NPL low temperature apparatus on which the design of the present apparatus is based. They also wish to thank Dr. R. le G. Burnett, Imperial Chemical Industries, Ltd., for helpful suggestions.

REFERENCE

1 Rees, W. P., Hopkins, B. E. and Tipler, H. R. Tensile and Impact Properties of Iron and Some Iron Alloys of High Purity. *J. Iron and Steel Inst.*, 1951, **169**, 157–168.

Order for Furnace Transformer

Associated Electrical Industries Ltd., Transformer Division, is supplying a large arc furnace transformer to the English Steel Corporation, Ltd., River Don Works, Sheffield, in conjunction with Birlec-Efco (Melting), Ltd. The transformer will be 20,000 kVA., 3-phase, 50 c./s., supplied at 33,000 V. and will be cooled by forced oil circulation through an oil-to-water heat exchanger. The equipment will comprise an untapped furnace transformer, an auto-wound voltage regulator to control transformer input voltage, and an auxiliary reactor, all contained in one tank. The reactor is included in order to meet special site conditions—its reactance is variable, and it can be completely cut out of circuit as desired, while the furnace is on load. The voltage regulator and the auxiliary reactor will have tappings connected to two separate motor-operated on-load tap-changers of the resistor transition type. Both tap-changers will be remote controlled from the control panel by the furnace operator.

Copper and Copper Alloys

A Survey of Technical Progress During 1959

By E. Voce, Ph.D., M.Sc., F.I.M.

Copper Development Association

Continued progress has been made in the past year in the metallurgy of copper and its alloys, and in the various sections of this review the author discusses the principal items of interest concerning such aspects as extraction, fabrication, finishing, properties and testing.

(*continued from page 252 of the December issue*)

Corrosion

Stress Corrosion

Mention has already been made of the addition of silver or tin to aluminium-bronze as a protection against stress corrosion.[78] Further publications on this development are those of Klement, Maerseh and Tully[88, 89] and of Norden,[90] while a nickel-iron aluminium-bronze containing silicon is claimed in a British patent[91] to be similarly resistant. The paper by Norden[90] also describes copper alloyed with about 2% of nickel and 0·6% of silicon as equally satisfactory from the point of view of stress corrosion, though the work of Robertson, Grenier, Davenport and Nole[92] indicates that material of this composition is susceptible to stress corrosion cracking in ammonia, to an extent depending on the degree of cold work and the condition of heat treatment.

More fundamental in character is the work of Forty[93] and of Graf.[94] Forty puts foward the view that stress corrosion cracking in α-brass is dependent upon pre-existing slipbands, the material between which is sufficiently hardened to support brittle fracture, while the experiments of Graf differentiate between the action of chemical reagents and mercury on the grain boundaries of solid solution alloys, including copper-zinc and copper-gold. Mercurous nitrate tests by Bobylev[95] on a wide range of binary copper-base alloys have led him to conclude that stress corrosion cracking is influenced by the solubility of the alloying element in mercury. For example, no cracking was observed in alloys of copper with nickel or cobalt, which are insoluble in mercury.

Intercrystalline cracking has been observed by Bailey[96] to occur in various β-brasses when stressed to a sufficient degree in ordinary air. He reports that the presence of moisture is essential for this type of failure, which does not take place in dry argon or dry air.

Bem[97] has examined the influence of phosphorus and of arsenic, used as inhibitors of dezincification, on the intercrystalline corrosion of aluminium-brass in sea water containing sulphuretted hydrogen. More than 0·02% of phosphorus makes the alloy susceptible to intercrystalline corrosion, as also does 0·1% of arsenic. Arsenic is, however, much less dangerous than phosphorus, and the restricted quantities normally present appear to be harmless.

Corrosion Fatigue and Cavitation

A most unusual instance of corrosion fatigue in hard-drawn stranded copper conductors wound on drums has been reported by Blazey.[98] Severe cracking had occurred after a relatively short period of storage and handling in rail transport. The trouble was attributed to the use of certain Australian hard woods for the drums which exuded corrosive organic vapours. These, coupled with the vibration of transport, were apparently sufficient to cause failures by corrosion fatigue. Royez and Pomey[99] describe corrosion fatigue tests in water on copper and copper with 4% of nickel and 1% of silicon, among other materials. They tried a variety of different inhibitors in the water and protective coatings on the metals, and found zinc-chromium plating to be particularly effective in combating corrosion fatigue.

Since cavitation damage is generally ascribed to mechanical causes, it is somewhat surprising to learn from the work of Tytell, Burnett and Preiser[100] that it can be mitigated in the case of high tensile brass and steel by means of cathodic protection. The current densities required are, however, greater than those normally associated with the cathodic protection of structures and ships.

The Influence of Light

Sunlight or other intense illumination, which ordinarily accelerates corrosion processes in metals, has been found to have exactly the opposite effect in the case of the oxidation of copper, the rate of growth of the oxide film being actually retarded by the irradiation.[101]

Markovic, Balasa and Esih[102] have observed the formation of a curiously photo-active layer on copper by etching in a mixture of 3 parts by volume of nitric acid, 2 parts of hydrochloric acid and 3 parts of water. A reddish surface film, formed immediately after removal of the copper from the bath, is said to turn black under illumination.

Protective Coatings for Steel

In a recent Russian investigation,[103] in which steel coated with a number of different deposits was tested under tropical conditions of high humidity, copper-tin, copper-tin-zinc and copper-cadmium alloys gave the best protection. Sacrificial coating metals, such as zinc and cadmium, proved useless under these conditions, unless they were further protected by chromate treatment. As an undercoating for nickel and chromium on steel, Gore[104] found bronze to be superior to an equal thickness of copper. Bronze and chromium, without

nickel, gave good corrosion-resistance, though the deposit tended to deteriorate in appearance. Tests by Rose and Pierce[105] indicate that a copper undercoat prior to a sulphur-containing bright nickel deposit is generally beneficial, though it is of little value under grey or sulphur-free nickel, while Dettner[106] concludes that copper deposits from cyanide baths give better protection as undercoatings for nickel and chromium on steel than those from acid solutions.

Corrosion Inhibitors

Tests on scales ranging from the laboratory bench through pilot plant to full-size refinery cooling towers have convinced Shields, Sorg and Stutz[107] that organic chromate inhibitors are particularly effective in protecting Admiralty brass and carbon steel against corrosion by river water. Phosphates gave fair protection but tended to deposit scale. Nevertheless, Powell[108] recommends a chromate-phosphate water treatment for the protection of copper tubes in condensers carrying water contaminated with ferrocyanide.

In the radiators of vehicle cooling systems, Levy[109] confirms the deleterious effect of triethanolamine on copper and of sodium nitrate on solder, and stresses the value of mercaptobenzothiazole (MBT) as a copper de-activator. Borax was found to be a satisfactory inhibitor of solder corrosion in systems containing ethylene glycol antifreeze solutions. Sussman, Nowakokski and Constantino[110] also refer to sodium nitrate as an addition to supply waters. The co-presence of sulphate was found to have an adverse effect on its power to inhibit corrosion of copper, brass and other metals, and its action is consequently somewhat unpredictable.

Radley and Stanley[111] have published a report of experiments which show that glucose strongly inhibits corrosion of copper and copper alloys, though it accelerates attack on aluminium. Noticing that acid constituents of plants are less corrosive towards brass than fruit juices of the same *p*H value, Desai[112] attributes this to the protection afforded by the greater colloidal content of the plants. He went on to study the influence of various colloids on the corrosion of brass in citric and mineral acids, and reports promising though somewhat variable results.

In connection with the stabilization of copper and nickel apparatus for processing uranium against corrosion by anhydrous hydrogen fluoride, Worthington [113] found that specimens were not attacked by hydrogen fluoride if they were first exposed to chlorine trifluoride at a higher temperature.

Oils and Detergents

The presence of small amounts of copper is known to be detrimental to the performance of oils in electrical transformers. Wood-Mallock, Steiner and Wood[114] give advice concerning chelating agents and oxidation inhibitors which suppress dissolution of copper, recommending particularly combinations of aromatic amino-acids or aromatic diamines with phenyl-β-naphthylamine or di-tert.-butyl-*p*-cresol.

Bukowiecki[115] reports studies of the corrosive behaviour of hot sulphur-containing oils on copper, bronze and 60 : 40 brass, paying particular attention to the action of motor oils on lead-bronze bearings. He also describes experiments on the corrosive effects of oils and greases which contain appreciable water, such as wet paraffin or wet diesel fuels, on copper and other metals. The work is still in progress.

A further branch of Bukowiecki's work[116, 117] is concerned with the influence of commercial detergents on copper-base materials. Experiments showed that copper, brass and tinned-copper were only slightly affected, whereas most other metals were corroded to a greater degree. An unexpected finding was, however, that if copper and aluminium were in galvanic contact, the aluminium became completely passive (owing presumably to superficial oxidation) thus concentrating attack upon the copper.

Corrosion Testing

The National Association of Corrosion Engineers[118] has issued a valuable report on micro-chemical methods suitable for the identification of corrosion products on copper and copper alloys. Constituents discussed in detail include oxides, chlorides, sulphates, sulphides, carbonates, silica, calcium, magnesium, sodium and ammonia, in addition to the metals in the material under examination. Some attention is also given to spectrographic methods.

Large differences in the results of comparable salt-spray porosity tests on tin-plated copper samples in more than twelve laboratories has been attributed by Fant[119] to variations in corrosivity within the individual cabinets. It would, however, seem wise to regard the results of such tests with caution.

Joining

Brazing and Welding

Herrschaft[120] maintains the view that much trial and error in finding the optimum gap to use when brazing dissimilar metals may be eliminated by simple calculations, showing whether the gap will expand or contract when heated and the approximate extent of the change. He gives a formula and nomogram for this purpose. More specifically, methods have been developed for the brazing of aluminium-bronze to Inconel with nickel-base filler metals in a hydrogen atmosphere,[121] and for bonding copper to tantalum in order to combine the thermal conductivity of copper with the resistance to corrosion of tantalum.[122]

It is interesting to learn that copper containing between 0·02 and 0·1% of boron has been patented as a filler rod for the inert-gas shielded arc welding of copper,[123] while another patented material[124] contains about the same amount of boron together with approximately 7% of nickel and 2% of chromium, the balance being copper. This alloy is said to have good strength and creep resistance at elevated temperatures, and is recommended for use in the manufacture of gas turbines. Perry[125] maintains that the addition of palladium to various filler alloys based on copper or the copper-silver eutectic can result in improved brazing quality.

Dessart and Liegeois,[126] investigating the weldability of copper-bearing steels, report that no difficulties were encountered unless the copper content exceeded 0·8%, which is well above the amount sufficient to retard rusting.

Cold Joining

Holmes[127] has examined the influence of relative interfacial movement and frictional restraint in the cold pressure welding of copper to aluminium. Among other conclusions, he found that the strength of the welds was solely dependent on the deformation of the copper

component, and was increased by preliminary sliding at the interface. Assessing the mechanism of pressure welding in roll bonding, Vaidyanath, Nicholas and Milner [128] record that a reduction in thickness of 60–70% was required to attain the maximum bond strength for copper and other non-ferrous metals. Factors advantageous to bonding were increase of pressure, temperature and roll diameter, and decrease of roll speed. Water vapour absorbed on the surface before rolling tended to inhibit welding.

An entirely different technique of cold joining consists of immersing the parts under pressure in a solution containing nickel hypophosphite.[129] Metallic nickel is deposited to form an adherent plating between the two metal surfaces. The process is applicable to copper and to brass.

Joints to Non-Metallic Materials

An anonymous note[130] mentions the development of a type of pressed and sintered glass with a coefficient of expansion approximating to that of copper, to which it can therefore be directly sealed. Jamieson[131] states that mechanically strong, gas-tight joints can be made to glass or refractory surfaces by activating them with graphite from a dispersion of colloidal graphite in alcohol and electroplating with copper, to which appropriate flanges can then be soft soldered. He states that such seals are satisfactory for use in high-vacuum systems. For metal-to-ceramic bonds exposed to severe service conditions, van Houten[132] recommends a mixture of titanium hydride and copper powders. He describes the technique of applying this type of cement.

Powder Metallurgy

Compacting

The Armour Research Foundation[133] has developed a new technique of compacting metal powder under a series of rapid blows, at the rate of 1,000 to 2,000 per minute. It is claimed that components of larger sectional area can be produced by this method than by static pressing. Thomas and Jones[134] report a small but significant increase in the density of 70 : 30 brass powders pressed in dies which were made to vibrate ultrasonically. Roll compacting has been studied by Evans and Smith[135] with special reference to the development of directional properties in copper rolled from powder. Directional variations of tensile properties were shown to be similar to those of rolled solid copper, at least for material with up to 16% porosity. Electrical resistivity was greater in the direction of rolling than across it. The particles of powder become elongated if the rolling pressure is sufficiently high.

Sintering

From an experimental study, Clapson and Robins[136] conclude that the mechanism of sintering in copper is that of diffusion of vacancies to the grain boundaries, where they are progressively destroyed. Pranatis, Castleman and Seigle[137] have also investigated the influence of grain boundaries, particularly in respect of rate of sintering. They report that the growth of necks between individual particles remained unaffected by the presence or absence of grain boundaries. Growth during the sintering of copper-tin and iron-copper powder mixtures has been investigated by Elliott[138] over a wide range of conditions.

Hot rolled strip is now being produced commercially from copper powder.[139] Samples indicated that the tensile strength was about 10% greater and the elongation about 1% higher than for conventially produced electrolytic copper strip. A British Patent[140] describes apparatus in which strip rolled from powder and coiled can be uncoiled within the sintering furnace, so that it can be re-rolled immediately.

Coated and Impregnated Powders

The Sherritt Gordon Technique of producing copper powder by pressure reduction with hydrogen from ammoniacal solutions has been applied to the coating of metallic and non-metallic powders.[141] Particular mention is made of metal-ceramic complexes made by this method. Frantsevich and Teodorvich[142] report an investigation of iron-copper compacts produced from copper-coated iron powder, and also from porous iron impregnated with a molten copper-iron alloy. They observed age-hardening properties after quenching from 1,000° C., and, for maximum response, reheating for 3 hours at 430° C. If heating were prolonged, there was a tendency for copper to spread along the grain boundaries of the iron-rich phase, and to cause a reduction in strength. Frommelt[143] mentions that copper-impregnated iron powder parts have been successfully used for boring bars, shanks, milling-cutter bodies and similar tools. The material is said to give improved performance, largely because of a substantial reduction in vibration.

Two notes have appeared on the preparation of powder-metallurgy products by introducing a powder of higher melting point into a liquid metal, with thorough mixing by ultrasonic vibration or similar means. One of these notes[144] is of Soviet origin, while the other[145] refers specifically to copper powder in molten lead, mentioning such applications as bearings, seals, gaskets and radiation shields. Matsukawa[146] claims that the wear of graphite brushes for electrical machines made from graphite powder coated with a copper-lead alloy is only half that of brushes produced in the normal way.

Physical Metallurgy

To do justice to the extensive literature on the physical metallurgy of copper and copper alloys which has appeared during the period under review would require far more space than that available. A rigorous selection has perforce been made, with an accent on papers which seem to contain information of potential value to industrial technology as distinct from academic science.

Constitution of Copper Alloys

Weill[147] and his collaborators[148] have determined the nature of certain secondary constituents found in complex high-strength brasses. Zinc-rich brasses containing aluminium, iron and manganese showed a star-shaped precipitate of a homogeneous solid solution of these three elements, while in another brass containing nickel, tin and lead in addition to those elements already named, there were branches of an ordered nickel-iron-aluminium phase around the original stars. Hornbogen[149] has followed the hardening which occurs when acicular α precipitates at between 200° C. and 300° C. from 60 : 40 brass previously quenched from the β condition.

Both Toner[150] and Cope[151] have investigated the sequences of changes which occur during the eutectoidal transformation of aluminium-bronze. Toner could find

no experimental evidence for ordering in the β-phase, while Cope recognised a new phase at temperatures below 400° C.

Measurements of electrical resistance and thermo-electric power on dilute copper-iron alloys have led Schumacher[152] to conclude that an iron-bearing phase remains even after drastic quenching; it becomes microscopically resolvable after ageing. Experiments by Williams[153] on the precipitation hardening of chromium-copper suggest to him that the observed effects arise not from the precipitate but from the displacements which it engenders in the matrix. Livingston[154] has observed that peak yield stress is attained in copper-cobalt alloys when the average radius of the precipitating particles is about 70 Å.

Vigdorovich, Krestovnikov and Mal'tsev[155] locate the eutectic of the copper-titanium system at 17·1% titanium and 870° ± 1° C., with a limiting solid solubility of 7·4% titanium at the eutectic temperature. They confirm the existence of the intermetallic compound Cu_3Ti, with a micro-hardness of 370 ± 15 kg/sq. mm. They have extended their work to cover ternary copper-titanium-aluminium alloys[156] and include some mechanical properties for materials containing 1–3% of titanium. Other ternary systems which have recently received attention are those of the copper-nickel-germanium[157] and copper-nickel-silicon[158] alloys. In the latter case, phases were separated by electrolysis in a solution of copper sulphate and ammonium citrate.

Diffusion

To determine the suitability of copper as a protective coating for uranium, measurements were made by Bean and Claire[159] of the interdiffusion rates of the two metals. In the course of the experiments, they developed a technique of bonding uranium powder to copper discs by hot pressing. Guy[160] has confirmed the results of previous investigators on the ratio of diffusivities of copper and zinc in various brasses, while Rhines and Dehoff[161] describe an experimental demonstration of the fact that zinc diffuses through copper more rapidly than tin.

Diffusion coefficients of cadmium[162] and of cobalt[163] into single crystals of copper have been determined in Japan. The figures given are $0{\cdot}935 \exp(-45{,}700/RT)$ and $5{\cdot}7 \exp(-55{,}200/RT)$, respectively. Schneider and Siegfriedt[164] have described methods for the diffusion coating of copper with silicon or titanium from the volatile chlorides of these elements, while Yukawa and Sinott[165] suggest that the well-known embrittlement of copper by the inward diffusion of bismuth is dependent upon grain boundary angles.

Oxidation, Reduction and Similar Processes

Several papers by Sartell and his collaborators have been published on the superficial oxidation at elevated temperatures of copper and certain copper alloys. One of these[166] deals with the mechanism of oxidation of high purity copper and the adherence of the oxide layer in relation to its plasticity, and another[167] with the oxidation of cupro-nickels containing up to 5% of nickel, while a third[168] indicates that the presence of 1% of magnesium in cupro-nickel reduces the rate of oxidation at temperatures between 500° C. and 700° C. The thermal oxidation of copper in air at 120°–350° C. has been shown by Trehan and Goswami[169] to be dependent upon the crystal orientation of the metal.

Mattsson and Schückher[170] have followed the hydrogen embrittlement of tough-pitch copper at temperatures ranging from 400° to 700° C., with various partial pressures of hydrogen. Observing that embrittlement does not take place during the initial stages of heating, but only after a period of incubation, and recognising that practical annealing treatments must be confined to this incubation period, they have defined maximum permissible temperatures and hydrogen concentrations for an incubation period of 1½ hours.

Evans and Fearnebough[171] have used a thermo-balance to assess the rate of reaction between copper and hydrogen sulphide at temperatures between 225° and 600° C. Above 400° C. the results were erratic, but below that temperature the reaction rate increased steadily with time. This they attribute to the growth of cupric sulphide upon the layer of cuprous sulphide initially formed.

The Mechanism of Fatigue

During recent years considerable work has been undertaken in attempts to elucidate the mechanism of fatigue failure in metals, and, in many cases, copper has been used for critical experiments. Recent contributions to this subject are those of Wood[172, 173] who has developed a technique of taper sectioning which permits effective magnifications sufficiently high to observe disintegration of the metal surface by fatigued slip bands. Ebner and Backofen[174] deformed single crystals of high purity copper by alternating bending at constant deflection, and observed the resultant hardening by continuous measurement of bending moment. They interpret their results to suggest that cross slip is essential for crack formation.

Tavernelli and Coffin[175] propose an equation involving number of cycles to failure and plastic strain to provide a simple method for predicting fatigue behaviour. The relationship was developed for annealed and cold worked copper, among other materials.

Electrical and Magnetic Properties

Hess and Pawlek[176] give the results of resistivity tests on high purity copper containing small quantities individually of oxygen, sulphur, selenium and tellurium. Their work also covered copper-rich alloys containing iron and phosphorus. As the result of an investigation of copper-chromium-silicon and copper-cobalt-silicon alloys of high conductivity, Gallo[177] seems to approve of the addition of silicon to industrial chromium-copper, though this practice is often deprecated.

According to Ahern, Martin and Sucksmith[178] certain high purity cupro-nickels containing up to 54 at.% of copper can undergo spontaneous magnetization. At the other end of the copper-nickel series, a high purity alloy containing 3·7% of nickel has been shown by Pugh[179] to have zero magnetic moment at room temperature, and less than a tenth of the magnetic moment of pure copper at temperatures down to 2°K. Zaborowski and Siarzewski[180] report experiments to show that the magnetic properties of several different brasses and bronzes containing small quantities of iron can be modified by variations in rolling and annealing schedules. Homogenization at 800° C. for 12 hours, or quenching from that temperature after 2½ hours, decreases magnetic susceptibility.

Testing and Analysis

" Springiness " of Copper Wire

Three papers presented at the Autumn Meeting of the

Institute of Metals in Stockholm this year refer to the question of "springiness" in fine copper wires for the winding of small electrical coils and machines. Such wires are generally enamelled, and the baking treatment applied to the enamel is expected simultaneously to anneal the wire so that it lies snugly in the coil when wound. The efficacy of the anneal, restricted in temperature by the presence of the enamel, is dependent on the quality of the copper, particularly in respect of minor impurities, and a simple but reliable test is required to assess its behaviour. Schückher and Nilsson[181] describe a spring elongation test devised for this purpose. It consists essentially of applying a known weight to the lower end of a vertically suspended coil of the wire under test, and measuring the extension of the coil. Carlén Kihlberg and Lundquist[182] record laboratory experiments to elucidate the factors that influence springiness, particularly in respect of final and interstage annealing. They based their work on the spring-elongation test. Comparable in scope is the third paper, that of Carter,[183] who discusses surface quality as well as springiness, and advocates deep shaving of the wire rod before drawing.

Analysis

For the determination of oxygen in copper, Harris and Hickman[184] recommend melting *in vacuo* in a graphite boat and measuring the pressure of the carbon monoxide evolved. The time taken is 15 minutes, sufficiently short to permit control of refinery melts. According to Galloway,[185] silver can be estimated in blister copper, and presumably therefore in other types of copper, by flame photometry after separation as the chloride, while Wiedmann[186] applies photometry to the rapid determination of chromium in chromium-copper. Cathro[187] has developed a polarographic technique for the determination of both arsenic and tellurium in copper.

A comprehensive scheme for the complete analysis of copper-base foundry alloys has been devised by the Centre Technique des Industries de la Fonderie,[188] and rapid methods suitable for foundry control are described by Wiedmann.[189] Pépin-Donat[190] indicates how zinc may be determined in brass within 15 minutes by the use of ethylenediamine tetra-acetic acid (E.T.D.A.). This same compound has been applied by Langford[191,192] and by Armet[193] to the analysis of brass and lead electroplating baths. It seems to be a remarkably versatile analytical reagent.

Miscellaneous

The quantity of copper required for the huge particle accelerators of modern physics is sometimes quite surprising. For example, the 7,000 MeV proton synchrotron, Nimrod, has 300 tons of copper in its rectangular hollow conductors.[194] Nose cones for Atlas and Thor missiles are claimed to be the largest closed-die copper forgings ever made.[195] They each weigh nearly a ton, and the high-conductivity of copper is necessary to dissipate frictional heat when the missiles re-enter the earth's atmosphere. Even in ordinary aviation, Carter[196] anticipates that some of the electric motors in aircraft will be called upon to operate at temperatures up to 260° C. in the near future, and at even higher temperatures later.

A recent development in the building industry is the manufacture of copper-clad roofing tiles,[197] which are at once durable, light and easy to fix. An experimental solar heating system, using over 2 tons of copper for roofing, interior panelling and pipes is under test in Arizona.[198] The copper roof serves as a collector of heat supplied by the sun.

It must not be forgotten that copper compounds, as well as the metal, are of great benefit to mankind. A modern example is the control of the dread disease bilharzia by the treatment of African waterways with copper sulphate to kill the snails which carry it.[199]

Looking to the years ahead, Sir Ronald Prain[200] anticipates bright prospects for the copper industry, provided only that the price can be maintained at a reasonably constant and economic level.

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HIGH DUTY ALLOYS, LTD. have closed their Hillington, Glasgow, office and opened a new one at De Quincey House, 48 West Regent Street, Glasgow, C.2 (Tel: Douglas 1500). This office will deal with all enquiries for castings, sheet, tube and extrusions for Scotland and Northern Ireland. Enquiries for forgings in that area will continue to be dealt with by the Manchester office at Colwyn Chambers, 24 Mosley Street, Manchester, 2.

THE agreement to acquire a 53·125% interest in the Solartron Electronic Group, Ltd., by Firth Cleveland, Ltd., will provide £900,000 immediately to ensure the adequate financing of Solartron's next five years of development and expansion. Mr. C. W. Hayward (chairman) and Mr. Gordon Harries (secretary) of Firth Cleveland, will join the Solartron Board. Mr. Hayward has agreed to accept the chairmanship and Mr. J. E. Bolton will be deputy chairman and managing director.

The Effect of Protective Coatings on the Properties of Ferritic Steel at 650° C.

By K. W. Mitchell, B.Sc. (Eng.), Wh.Sch., A.M.I.Mech.E.,

H. King, A.M.C.T., A.M.I.Mech.E. and E. A. Brandes, B.Sc., A.R.C.S., F.I.M.

Fulmer Research Institute, Ltd.

Prevention of oxidation and scaling of steel by the deposition of a protective coating of aluminium or chromium results in extended life under creep or fatigue stresses, providing that any softening of the steel produced by the coating process is more than compensated for by the improved oxidation resistance. This paper presents the results of tests on 12 s.w.g. sheet in mild steel (En.2A) and Mo-B, Mo-V, and Cr-Mo-V-W low alloy ferritic steels. Aluminium coatings were applied by hot-dipping and by metal spraying followed by a diffusion treatment, and chromium coatings by deposition from chromium chloride vapour with simultaneous diffusion. Chromising had an adverse effect on the core strength—of decreasing importance with increase in thickness of the core material—and suggestions are made for minimising this effect by modification of the process.

SURFACE treatments offer scope for future developments of materials for use at elevated temperature, whose present application is restricted by their poor oxidation resistance. Thus it may be possible to extend the use of low alloy ferritic steels at temperatures up to 650° C., and make them competitive with the more expensive austenitic steels, where the oxidation resistance is inherent.

Molybdenum steels are an example where, by surface protection, full use could be made of their good creep properties, providing they are unaffected by the temperature of the coating process, or if affected, the mechanical properties could be restored by heat treatment without reducing the effectiveness of the surface protection.

In the case of fatigue it is also important that the fatigue life of the coating should not be less than that of the basis material under the test conditions, since it is common experience that protective coatings with low fatigue endurance can seriously reduce the fatigue of the basis metal.

This investigation was carried out to find the effects of surface coatings on the tensile, creep, and fatigue properties at 650° C. of mild steel and three low alloy ferritic steels. The coatings were of the hot-dipped aluminium, aluminised (aluminium sprayed and subjected to a diffusion heat treatment), and chromised types, with and without subsequent heat treatment to restore the core properties. All tests were carried out on 12 s.w.g. sheet material.

Test Procedure

The steels chosen for this investigation were mild steel (En.2A) as-rolled and pickled; Mo-B normalised from 930° C.; Mo-V as-rolled, and also normalised 975° C. and tempered at 675° C.; and Cr-Mo-V-W air hardened from 1,060° C. and tempered at 680° C. The chemical analyses of these materials are given in Table I.

The protective coatings were applied as follows:—

(*a*) *Chromium Diffusion*—This was carried out by Diffusion Alloys, Ltd., by a process which has been described in the literature.[1] During the process the specimens were fully annealed, and a subsequent heat treatment was carried out in an attempt to restore the core properties.

(*b*) *Hot-Dipping in Aluminium*—Specimens were prepared by degreasing and pickling, and then given a copper flash in an acidulated solution of copper sulphate. They were then immersed in a bath of commercial purity aluminium held at 740 ± 10° C. for 2 minutes.

(*c*) *Aluminising—Diffusion of Metal Sprayed Coating*—This treatment was carried out by Metallisation, Ltd., in accordance with B.S.2569/1955, Part 2, Process C, and consisted of preparing the metal surfaces by grit blasting and spraying with metallic aluminium, followed by 15 minutes at 800° C. for diffusion of the aluminium to occur. The average coating thickness was 0·0055 in. and the coverage 2·61 g./sq. ft.

Tensile creep tests on specimens machined to the dimensions given in Fig. 1 were carried out in B.N.F.M.R.A. type creep units (1950)[2]. All specimens were heated to the test temperature (650° C.) in about 4 hours, and then soaked for 20 hours before the application of the required stress. The test temperature was maintained within ± 2° C. throughout the test.

TABLE I.—CHEMICAL ANALYSIS OF MATERIALS

Material	C %	Si %	Mn %	S %	P %	Cr %	Ni %	V %	Mo %	B %	W %
Mild Steel (En. 2A)..	0·055	—	0·50	0·022	0·009	—	—	—	—	—	—
Mo-B Steel..	0·14	0·22	0·53	0·034	0·010	—	—	—	0·42	0·004	—
Mo-V Steel..	0·09	—	0·5	—	—	0·39	—	0·53	0·26	—	—
Cr-Mo-W-V Steel ..	0·23	—	0·43	—	—	2·80	0·70	0·79	0·50	—	0·52

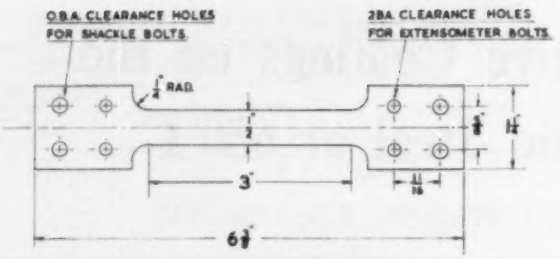

Fig. 1.—Creep test specimen.

Tensile tests were carried out at room temperature and at 650° C., using the same type of specimen and extensometer as used in the creep tests. The tests at 650° C. were carried out in accordance with B.S.1094/1943.

Fatigue tests were carried out in alternating flexure fatigue machines specially designed for this investigation. A description of this machine is given in a previous paper by Mitchell and King (1958)[3]. The specimens machined to the dimensions given in Fig. 2 were raised to the test temperature of 650° C. in 2 hours, and allowed to soak for 1 hour while calibration was taking place, after which the machine was set to give the required amplitude with zero mean stress and the test commenced.

Calculations of the surface stresses were based on the theory of elastic bending, where deflection and bending moment are proportional to stress. Consequently, due to the change in modulus of elasticity during cyclic loading, scaling, crack formation, and in some cases plastic flow, the values derived for the stresses are only nominal. The limit of proportionality was not measurably exceeded during calibration to find the stress-deflection constant.

When materials were subjected to deflections giving nominal stresses in excess of the limit of proportionality, the error between the true surface stress and the nominal would be increased with increasing stress. Above the yield stress the error would become large. With those materials where the coating treatment had softened the core, the static yield point was sometimes exceeded. This was especially so with mild steel, where the core was very weak, with the coating taking a large percentage of the total bending moment. For evaluation of the results for his material, the nominal stress values given are based on the nominal surface stress deflection ratio for the uncoated specimens. Thus, comparison has been

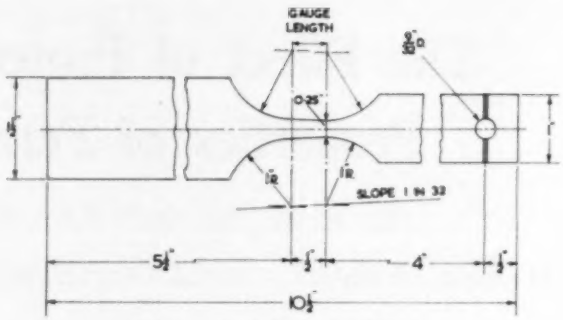

Fig. 2.—Fatigue test specimen.

made in reality on equivalent surface strains. With the other materials the strengthening effect of the coatings was negligible as shown by the stress-deflection ratio of the coated specimens being practically the same as for the uncoated.

All specimens were surface ground longitudinally to remove scale and surface imperfections prior to surface treatment.

Results of Tests

Tables II–V show, in order, the effect of the coatings on the tensile properties at room temperature and 650° C., on mild steel and Mo-B, Mo-V, and Cr-Mo-V-W steels, and in Table VI the results at 650° C. have been summarised. Tables VII–X show the effect on the creep properties, giving, for each test condition, the percentage creep for various times and the rupture times when applicable. Table XI summarises these results on a qualitative basis. Table XII shows the effect of the coatings on the fatigue strength for a range of endurances. The creep and fatigue data given in these tables have been interpolated from the creep and fatigue curves, which, for brevity, have not been included in this paper.

Chemical Analysis and Hardness Tests

The effect of the thermal treatment given to the specimens during processing was investigated and it was shown that considerable variation in hardness occurred. Table XIII shows the variation in hardness of chromised Mo-B specimens. Analysis was made to determine the reduction in carbon content in the other steels. This was done by grinding off approximately 0·005 in. from the coated surfaces before taking the sample for analysis.

TABLE II.—TENSILE PROPERTIES AT ROOM TEMPERATURE AND 650° C. OF MILD STEEL (En 2A)

Test Ref. No.	Description	At Room Temperature			At 650° C.		
		0·5% Proof Stress (tons/sq. in.)	Max. Stress (tons/sq. in.)	Elongation (% on 2 in.)	0·5% Proof Stress (tons/sq. in.)	Max. Stress (tons/sq. in.)	Elongation (% on 2 in.)
4	As-received.	20·2	22·8	34·5	—	—	—
60		—	—	—	3·56	4·87	90
19		—	—	—	3·69	4·75	79
34	Hot-dipped aluminium coating.	17·6	21·4	34	—	—	—
35		—	—	—	4·02	5·2	71
41		—	—	—	3·48	5·06	66
62	Aluminised coating.	13·3	18·0	22	—	—	—
63		—	—	—	3·28	4·43	48
64		—	—	—	3·25	4·43	54
36	Chromised coating.	6·74	16·6	47	—	—	—
45		—	—	—	2·23	4·65	62
46		—	—	—	2·39	4·55	63
40	Chromised coating + heat treatment.	8·45	17·7	43	—	—	—
41		—	—	—	2·92	4·29	71
49		—	—	—	2·70	4·31	61

TABLE III.—TENSILE PROPERTIES AT ROOM TEMPERATURE AND 650° C. OF Mo-B STEEL

Test Ref. No.	Description	At Room Temperature			At 650° C.		
		0·5% Proof Stress (tons/sq. in.)	Max. Stress (tons/sq. in.)	Elongation (% on 2 in.)	0·5% Proof Stress (tons/sq. in.)	Max. Stress (tons/sq. in.)	Elongation (% on 2 in.)
F30	As-received.	35·4	42·1	17	—	—	—
F31		—	—	—	19·5	20·2	28
F32		—	—	—	20·4	21·9	24
F45	Hot-dipped aluminium coating.	35·2	41·0	15·5	—	—	—
F44		—	—	—	18·1	18·6	37
F46		—	—	—	18·5	19·4	25
F24	Aluminised coating.	30·5	38·2	22·5	—	—	—
F25		—	—	—	15·3	16·6	35
F26		—	—	—	14·9	16·7	34
F36	Chromised coating.	15·4	26·8	29	—	—	—
F37		—	—	—	9·1	12·7	39
F38		—	—	—	8·6	12·7	39
F 2	Chromised coating + heat treatment.	16·1	25·8	31	—	—	—
F 3		—	—	—	7·9	11·4	45
F 4		—	—	—	8·9	12·4	40
F67	Chromised coating + heat treatment.	18·7	29·6	25	—	—	—
F47		33·3	40·3	16*	—	—	—
F48		—	—	—	17·3	18·4	26*
F49		—	—	—	17·6	18·3	22*

* It was clear from microscopic examination that these specimens had suffered much less decarburisation than other heat-treated chromised specimens.

TABLE IV.—TENSILE PROPERTIES AT ROOM TEMPERATURE AND 650° C. ON MO-V STEEL

Test Ref. No.	Description	At Room Temperature			At 650° C.		
		0·5% Proof Stress (tons/sq. in.)	Max. Stress (tons/sq. in.)	Elongation (% on 2 in.)	0·5% Proof Stress (tons/sq. in.)	Max. Stress (tons/sq. in.)	Elongation (% on 2 in.)
C131	As-received, in normalised and tempered condition.	25·3	34·4	20	—	—	—
C108		—	—	—	14·1	17·9	31
C130		—	—	—	14·3	17·7	30
C113	Hot-dipped aluminium coating.	27·8	37·4	15	—	—	—
C117		—	—	—	14·1	17·8	37
C124		—	—	—	14·8	18·5	44
C120	Aluminised coating.	22·3	33·8	18	—	—	—
C117		—	—	—	13·9	17·6	29
C119		—	—	—	14·3	18·2	19·5*
C 92	Chromised coating.	13·8	24·2	33·5	—	—	—
C 94		—	—	—	8·34	12·4	24·5
C 97		—	—	—	9·27	13·6	32·5
C 89	Chromised coating + heat-treatment.	12·7	24·4	33	—	—	—
C 96		—	—	—	8·83	12·3	35
C 99		—	—	—	8·74	11·1	36
C 28	As-rolled material with chromised coating.	14·7	25·4	33	—	—	—
C 29		—	—	—	9·33	13·8	32
C 74		—	—	—	9·38	14·0	31
C 53	As-rolled material with chromised coating + heat treatment.	19·9	28·1	19	—	—	—
C 53		—	—	—	12·3	14·2	19
C 54		—	—	—	12·3	13·5	28

* This value is low as fracture occurred at the end of the gauge length.

Note.—The material which had been chromised as-rolled responded to heat treatment, presumably due to less decarburisation and grain growth than material which had been chromised in the heat treated condition.

TABLE V.—TENSILE PROPERTIES AT ROOM TEMPERATURE AND 650° C. OF Cr-Mo-V-W STEEL

Test Ref. No.	Description	At Room Temperature			At 650° C.		
		0·5% Proof Stress (tons/sq. in.)	Max. Stress (tons/sq. in.)	Elongation (% on 2 in.)	0·5% Proof Stress (tons/sq. in.)	Max. Stress (tons/sq. in.)	Elongation (% on 2 in.)
H 1	As-received.	64·4	66·4	11	—	—	—
H 2		—	—	—	32·0	34·2	18·5
H 3		—	—	—	30·8	35·4	17
H18	Hot-dipped aluminium coating.	60·8	66·5	12	—	—	—
H34		—	—	—	26·8	31·6	15
H30		—	—	—	27·6	31·1	20
H35	Aluminised coating.	53·1	64·6	12	—	—	—
H36		—	—	—	20·2	22·6	23
H27		—	—	—	20·0	21·8	34
H50	Blank aluminised diffusion treatment (½ hr. at 800° C.).	43·5	55·5	10	—	—	—
H51		—	—	—	15·4	19·3	31
H52		—	—	—	16·1	20·1	25
H 4	Chromised coating.	28·8	40·2	14·5	—	—	—
H12		—	—	—	14·3	17·3	16
H13		—	—	—	15·7	18·6	15
H38	Chromised coating + heat treatment.	50·3	56·0	12	—	—	—
H39		—	—	—	23·0	24·8	19
H40		—	—	—	21·9	23·9	15·5

TABLE VI.—SUMMARY OF EFFECT ON TENSILE STRENGTH AT 650° C.

Coating Treatment	En. 2A		Mo-B Steel		Mo-V Steel		Cr-Mo-V-W Steel	
	0·5% Proof Stress (tons/sq. in.)	Max. Stress (tons/sq. in.)	0·5% Proof Stress (tons/sq. in.)	Max. Stress (tons/sq. in.)	0·5% Proof Stress (tons/sq. in.)	Max. Stress (tons/sq. in.)	0·5% Proof Stress (tons/sq. in.)	Max. Stress (tons/sq. in.)
Uncoated	3·62	4·81	20·0	21·0	14·2	17·8	31·4	34·8
Hot-dipped aluminium	3·75	5·13	18·3	19·0	14·4	18·1	27·2	31·3
Aluminised	3·25	4·44	15·1	16·6	14·1	17·9	20·1	22·2
Chromised	2·31	4·59	8·8	12·7	9·35*	13·9*	15·0	17·9
Chromised + heat treatment	2·81	4·30	17·4	18·3	12·2*	13·8*	22·4	24·3

* Figures given are for material chromised as-rolled.

TABLE VII.—SUMMARY OF CREEP PROPERTIES AT 650° C. OF En.2A STEEL

Treatment Symbol	Ref. No.	Stress (tons/sq. in.)	Creep % (hr.) 50	100	300	500	1,000	1,500	2,000	3,000	4,000	6,000	8,000	Duration (hr.)	Final Creep (%)	
A	39	0·5	0·30	0·56	1·20	1·80	2·90	3·70	4·15	4·90	5·45	—	—	4,395	6·9	B
B	28	—	0·28	0·32	0·61	0·82	1·26	1·60	2·0	2·4	2·8	3·2	3·6	8,327	3·62	UB
C	37	—	0·13	0·19	0·40	0·55	0·87	1·20	1·4	1·7	2·0	—	—	4,676	2·12	UB
D	19	—	0·04	0·07	0·16	0·25	0·46	0·64	0·8	1·12	1·38	1·8	2·16	8,797	2·4	UB
E	59	—	0·05	0·10	0·22	0·35	0·51	0·66	0·82	1·06	1·30	1·77	2·25	8,921	2·5	UB
E	44	—	0·06	0·09	0·17	0·23	0·26	—	—	—	—	—	—	1,008	0·36	UB
A	15	0·75	0·88	1·46	—	—	—	—	—	—	—	—	—	290	3·34	UB
B	29	—	0·70	1·30	3·0	4·8	8·35	—	—	—	—	—	—	1,010	8·4	UB
C	36	—	0·30	0·50	1·12	1·64	2·76	3·7	4·4	5·6	—	—	—	3,632	6·16	UB
D	51	—	0·34	0·48	1·36	2·24	4·5	—	—	—	—	—	—	1,000	4·5	UB
E	58	—	0·23	0·38	0·86	1·26	2·42	3·78	—	—	—	—	—	1,855	5·22	UB
A	14	1·0	1·62	2·90	—	—	—	—	—	—	—	—	—	237	6·9	B
B	30	—	1·53	2·68	—	—	—	—	—	—	—	—	—	245	6·13	UB
C	35	—	0·60	0·90	2·40	3·80	7·3	—	—	—	—	—	—	1,370	10·2	UB
D	52	—	0·86	1·42	3·70	5·36	—	—	—	—	—	—	—	582	6·1	UB
E	57	—	0·50	0·90	2·50	4·2	—	—	—	—	—	—	—	845	8·4	UB

B—Broken. UB—Unbroken.

Treatment Key:
A—As-received.
B—Hot-dipped aluminium coating.
C—Aluminised coating.
D—Chromised coating.
E—Chromised coating + heat treatment (910° C., ½ hr., water quenched).

The results show a reduction in carbon content on chromising as follows :—

	From	To
Mild steel	0·055%	<0·03%
Mo-B steel	0·14%	<0·03%
Mo-V steel	0·09%	<0·03%
Cr-Mo-V-W steel	0·23%	<0·13%

Metallographic Examination

The specimens were examined metallographically after testing. In the case of the uncoated mild steel, a coarse grained decarburised zone was found on the surface, with oxide penetration down the boundaries of the grains. This is shown in Figs. 3 and 4. Decarburising was generally absent from the other steels tested in the uncoated condition, and these show oxide penetration down cracks (see, for example, Fig. 5 of uncoated Mo-V steel and Fig. 6 of uncoated Mo-B steel). It is clear that oxidation has accelerated failure by penetration down cracks. Oxidation through aluminium coated specimens took a similar form to the oxidation in the uncoated materials once the aluminised coating had been penetrated or had developed porosity. Typical oxidation of aluminium coated steels is shown in Fig. 7, which shows oxide penetration down the large surface grains on specimens coated by hot-dipping, and Fig. 8 which shows the same thing with an aluminised surface.

In uncoated alloy steels and in alloy steels coated with aluminium there was no obvious decarburisation, presumably because the alloy steels contained more stable carbides, but oxidation through aluminium coatings proceeded down cracks or porosity (see, for example, Figs. 9, 10 and 11). In the case of all the

TABLE VIII.—SUMMARY OF CREEP PROPERTIES AT 650° C. OF Mo-B STEEL

Treatment Symbol	Ref. No.	Stress (tons/sq. in.)	Creep % (hr.) 50	100	300	500	1,000	1,500	2,000	3,000	4,000	6,000	Duration (hrs.)	Final Creep (%)	
A	F27	2·0	0·05	0·08	0·20	0·32	0·60	0·82	1·12	—	—	—	2,395	2·04	B
A	F13	—	0·10	0·16	0·38	0·62	1·20	2·40	—	—	—	—	1,709	5·4	B
B	F20	—	0·03	0·04	0·08	0·13	0·25	0·36	0·48	0·84	—	—	3,342	1·17	UB
C	F39	—	0·11	0·15	0·24	0·30	0·42	0·48	0·55	0·75	1·10	2·20	7,436	3·89	B
D	F 6	—	0·04	0·09	0·26	0·54	—	—	—	—	—	—	715	3·15	B
E	F 9	—	0·10	0·20	0·70	1·66	—	—	—	—	—	—	854	6·6	UB
A	F16	2·5	0·11	0·17	0·44	0·70	1·44	2·04	—	—	—	—	1,725	3·21	B
A	F14	—	0·11	0·18	0·44	0·71	1·18	1·70	—	—	—	—	1,735	2·83	B
B	F19	—	0·11	0·17	0·42	0·67	1·50	2·66	—	—	—	—	1,903	4·25	UB
B	F22	—	0·14	0·20	0·51	0·98	2·56	4·76	—	—	—	—	1,711	6·42	UB
C	F40	—	0·23	0·34	0·73	1·08	1·87	2·42	2·80	3·95	—	—	3,556	5·8	B
D	F10	—	1·08	—	—	—	—	—	—	—	—	—	77	1·85	B
E	F 8	—	0·24	0·77	—	—	—	—	—	—	—	—	196	2·5	UB
F	F69	—	0·12	0·20	0·59	—	—	—	—	—	—	—	462	4·79	UB
A	F51	3·0	0·17	0·33	1·05	1·92	—	—	—	—	—	—	749	3·8	B
A	F12	—	0·80	1·60	4·40	—	—	—	—	—	—	—	334	5·34	UB
B	F21	—	0·16	0·24	0·78	1·46	3·70	—	—	—	—	—	1,074	4·23	UB
C	F41	—	0·24	0·42	0·90	1·40	2·35	2·98	3·68	—	—	—	2,459	5·65	B
E	F 7	—	3·70	—	—	—	—	—	—	—	—	—	98	5·67	UB

B—Broken. UB—Unbroken.

Treatment Key:
A—As-received.
B—Hot-dipped aluminium coating.
C—Aluminised coating.
D—Chromised coating.
E—Chromised coating + heat treatment (normalised 930° C.).
F—Chromised coating + heat treatment (normalised 980° C.).

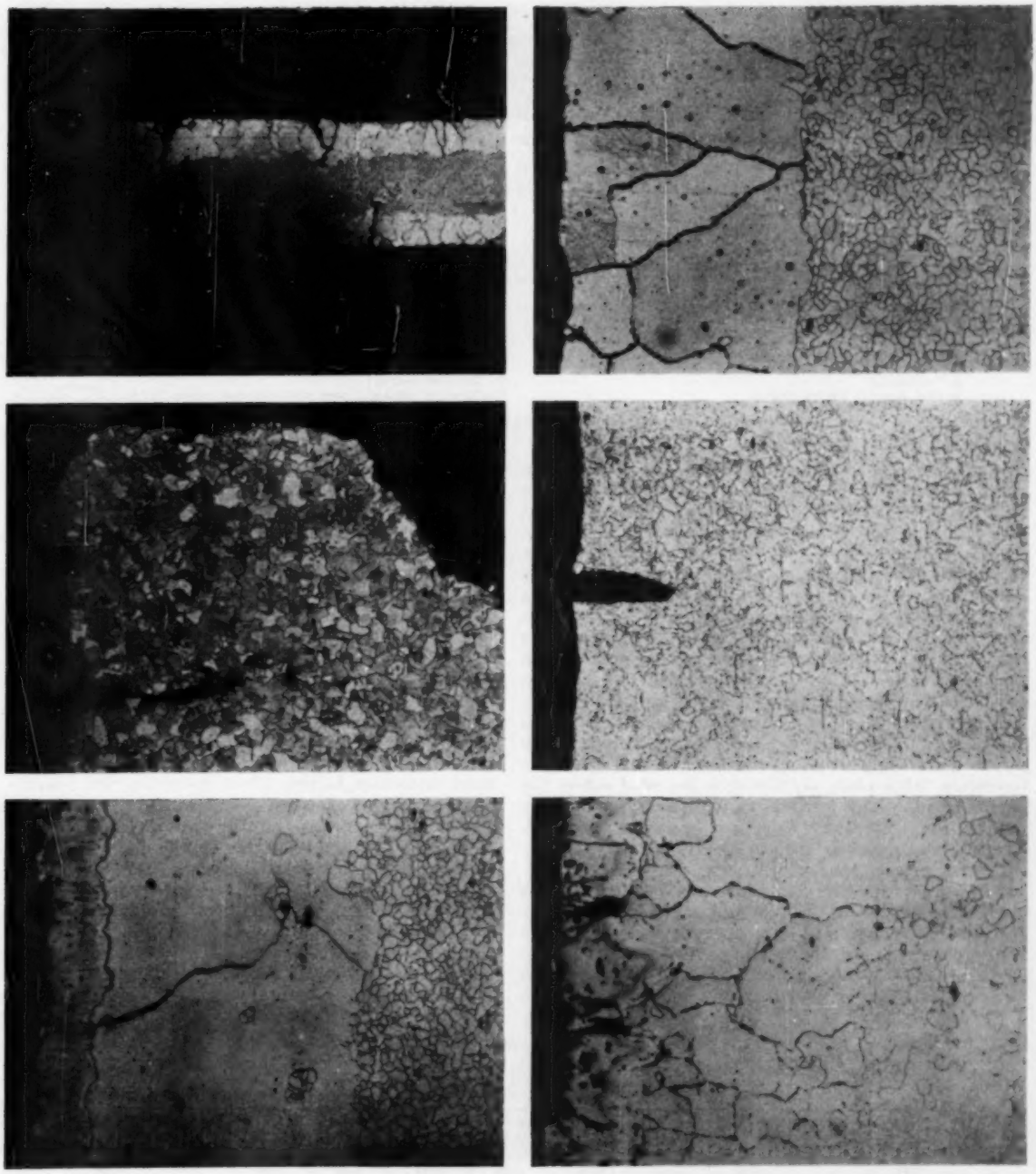

Fig. 3 (top left).—Fatigue test piece in En. 2A steel, uncoated ; ± 2·0 tons/sq. in., endurance 193¼ hours ; showing depth of oxide penetration and grain coarsening. × 10

Fig. 4 (top right).—The same piece as Fig. 3, showing oxide penetration down boundaries of the coarse surface grains shown in Fig. 3. × 100

Fig. 5 (middle left).—Fatigue test piece in Mo-V steel, uncoated ; ± 8·0 tons/sq. in., endurance 367 hours ; showing spreading oxide penetration and remains of oxide on the fractured edge. × 100

Fig. 6 (middle right).—Fatigue test piece in Mo-B steel, uncoated ; ± 7·5 tons/sq. in., endurance 229 hours ; showing typical form of oxide penetration. × 100

Fig. 7 (bottom left).—Fatigue test piece in En. 2A steel, hot-dipped aluminium coated ; ± 2·23 tons/sq. in., endurance 439 hours ; showing oxide penetration down large surface grains. × 100

Fig. 8 (bottom right).—Fatigue test piece in En. 2A steel, aluminised ; ± 2·95 tons/sq. in., endurance 410 hours ; showing oxide penetration down large surface grains. × 100

TABLE IX.—SUMMARY OF CREEP PROPERTIES AT 650° C. OF Mo-V STEEL

Treatment Symbol	Ref. No.	Stress (tons/sq. in.)	Creep % (hr.)											Duration (hr.)	Final Creep (%)	
			50	100	300	500	1,000	1,500	2,000	3,000	4,000	6,000	8,000	10,000			
A	C 87	2·0	0·01	0·02	0·03	0·03	0·05	—	—	—	—	—	—	—	1,032	0·05	UB
B	C115	—	0	0	0	0	0	0	0	—	—	—	—	—	2,882	0	UB
C	C113	—	0·02	0·03	0·05	0·07	0·09	0·14	0·22	—	—	—	—	—	2,501	0·31	UB
D	C 21	—	0·03	0·05	0·10	0·17	0·46	—	—	—	—	—	—	—	1,032	0·48	UB
E	C 22	—	0·04	0·05	0·06	0·10	0·17	0·25	0·33	0·60	1·10	—	—	—	4,085	1·10	UB
A	C100	3·0	0·02	0·02	0·03	0·04	0·12	0·35	0·91	—	—	—	—	—	2,300	2·38	B
A	C 86	—	0·02	0·03	0·04	0·04	0·11	—	—	—	—	—	—	—	1,007	0·11	UB
B	C125	—	0·04	0·05	0·05	0·05	0·05	0·05	0·05	0·05	0·06	0·08	0·11	—	9,547	0·12	UB
C	C116	—	0·05	0·06	0·11	0·20	0·60	—	—	—	—	—	—	—	1,574	1·41	B
D	C 12	—	2·0	—	—	—	—	—	—	—	—	—	—	—	97	8·6	UB
D	C 4	—	0·23	0·58	8·40	—	—	—	—	—	—	—	—	—	313	9·2	UB
E	C 34	—	0·13	0·17	0·34	0·88	3·5	—	—	—	—	—	—	—	1,062	4·07	B
A	C 85	4·0	0·04	0·05	0·07	0·11	0·38	—	—	—	—	—	—	—	1,395	1·6	B
B	C127	—	0·04	0·05	0·08	0·11	0·16	0·20	0·24	0·35	0·46	0·77	1·28	2·45	10,392	3·63	B
C	C128	—	0·07	0·11	0·29	0·55	—	—	—	—	—	—	—	—	917	2·01	B
D	C 13	—	1·48	4·2	—	—	—	—	—	—	—	—	—	—	120	5·2	UB
E	C 23	—	—	—	—	—	—	—	—	—	—	—	—	—	73½	6·6	UB
F	C 84	—	0·15	0·70	—	—	—	—	—	—	—	—	—	—	174	9·56	UB

B—Broken. UB—Unbroken.

Treatment Key :
A—As-received.
B—Hot-dipped aluminium coating.
C—Aluminised coating.
D—Chromised coating.
E—Chromised coating + heat treatment (normalised 975° C., ½ hr. and tempered 690° C., 3 hr.). } As-rolled condition before chromising
F—Chromised coating : heat treated (normalised 975° C., ½ hr. and tempered 690° C., 3 hr.) before and after chromising.

chromised specimens, however, a decarburised zone was found on the surface and this was confirmed by the chemical analysis already reported. This was believed to be due to the formation of the stable chromium carbide, and was shown to have taken place during the chromising process and not during test. It is clear that during the heating up of the steels to the chromising temperature, the steel is ferritic, but no decarburisation of the steel takes place. When the temperature is raised to that at which chromium is deposited on the surface, the steel becomes austenitic and the diffusion rate of carbon in austenite at this temperature is slow. The formation of chromium carbide during the actual deposition of the chromium is therefore comparatively slow. On cooling down in the box, however, carbide formation takes place rapidly once the steel enters the ferrite range. This carbide formation is particularly rapid in the temperature range just below the austenite-ferrite transformation (i.e. in the range 700–900° C., depending on composition).

On re-heat treating the chromised samples, rapid heating from 680° C. to the normalising temperature shortens the time in this temperature range and so helps to prevent further loss of carbon from the core. None the less, some decarburisation, usually accompanied by appreciable grain growth, was found in most of the chromised specimens after test. Metallographic examination confirmed that, provided the coating remained unbroken, the oxidation resistance conferred by chromising was better than that given by aluminium coating whether by hot dipping or aluminising.

A further feature of the chromised fatigue specimens was the presence of strain markings in the grains near the surface, showing that the material here had been stressed well above the elastic limit. Typical examples are shown in Figs. 12, 13 and 14.

Discussion of Results

This experimental work has demonstrated quite clearly that the influence of the coating process on the mechanical properties of the basis metal is one of the most important factors which determine the resistance of the combined effects of oxidation and creep or fatigue. The chromising process has the greatest effect. Not only is it carried out at a relatively high temperature, but the chromium causes marked decarburisation by the formation of a relatively stable chromium carbide. Grain growth takes place as a result of the high temperatures and this is aggravated by decarburisation. Decarburisation is most rapid in practice when the steel is at a temperature just below the austenite-ferrite transformation temperature, i.e. during heating up or cooling down,

TABLE X.—SUMMARY OF CREEP PROPERTIES AT 650° C. OF Cr-Mo-V-W STEEL

Treatment Symbol	Ref. No.	Stress (tons/sq. in.)	Creep % (hr.)							Duration (hr.)	Final Creep (%)	
			50	100	300	500	1,000	1,500	2,000			
A	H37	3·0	0·08	0·12	0·22	0·35	0·76	1·34	2·20	2,700	4·6	B
B	H21	—	0·06	0·10	0·22	0·33	0·66	1·08	—	1,723	1·31	UB
C	H35	—	0·16	0·22	0·48	0·72	1·44	2·94	—	1,699	4·12	B
D	H16	—	0·01	0·02	0·04	0·05	0·10	—	—	1,171	0·11	UB
E	H42	—	0·06	0·09	0·20	0·28	0·47	0·70	0·90	2,182	1·00	UB
A	H47	4·0	0·12	0·18	0·42	0·72	—	—	—	981	2·01	B
A	H32	—	0·16	0·25	0·74	1·65	—	—	—	502	1·65	B
B	H22	—	0·04	0·16	0·39	0·64	1·83	—	—	1,240	2·98	B
C	H34	—	0·22	0·35	0·76	1·44	—	—	—	671	2·68	B
D	H16	—	0·02	0·03	0·05	0·07	0·12	—	—	1,340	0·17	UB
E	H45	—	0·08	0·12	0·24	0·40	—	—	—	914	0·78	B
A	H46	6·0	0·22	0·32	0·96	2·28	—	—	—	328	2·84	B
B	H23	—	0·20	0·50	2·12	—	—	—	—	340	3·07	B
C	H33	—	2·68	—	—	—	—	—	—	77	5·6	UB
D	H14	—	0·07	0·09	0·17	0·32	—	—	—	382	0·48	B
E	H44	—	0·14	0·22	—	—	—	—	—	240	0·53	B

B—Broken. UB—Unbroken.

Treatment Key :
A—As-received.
B—Hot-dipped aluminium coating.
C—Aluminised coating.
D—Chromised coating.
E—Chromised coating + preheated to 680° C., 1,060° C. ½ hr. air-cooled, and tempered 680° C., 3 hr.

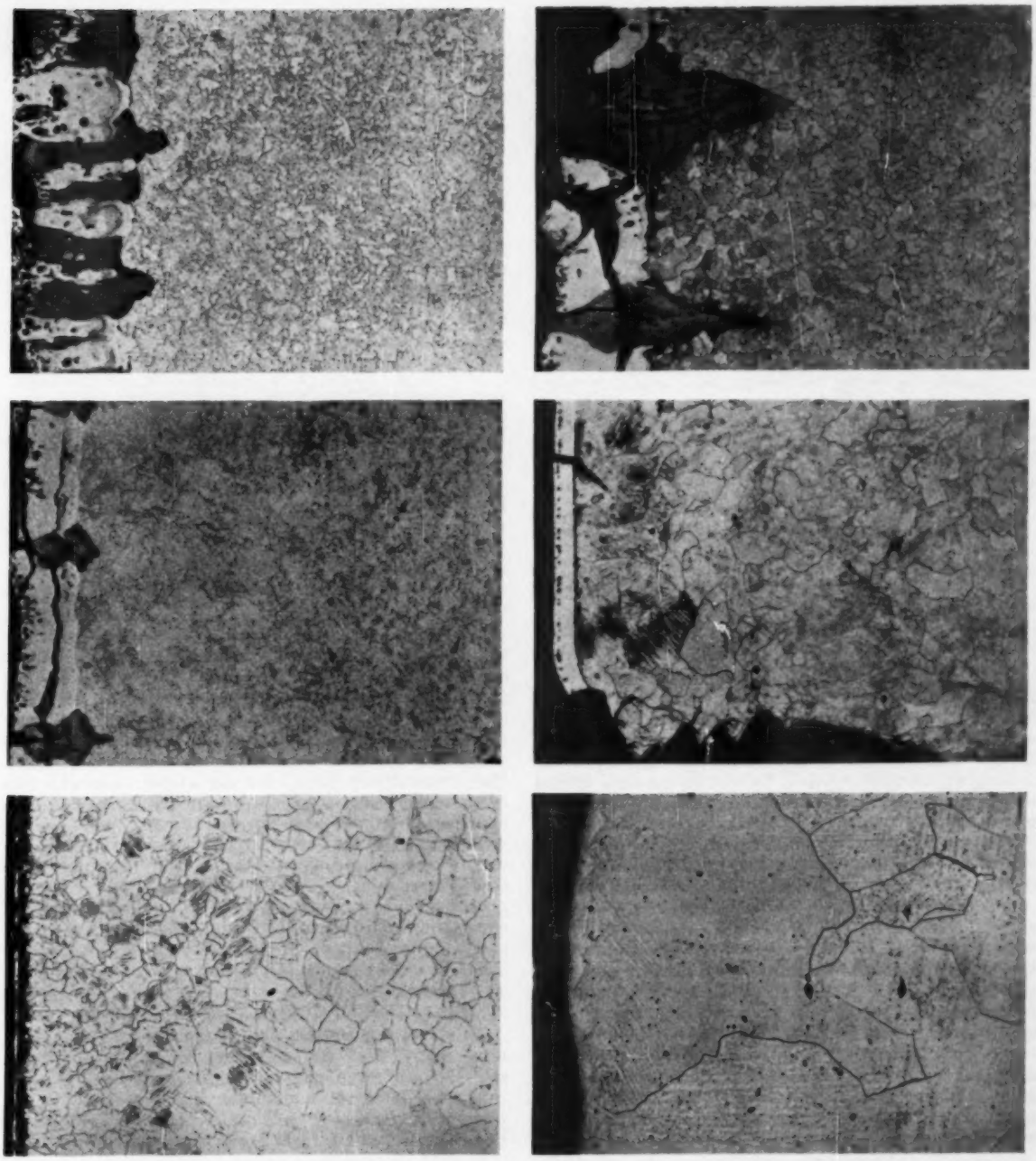

Fig. 9 (top left).—Fatigue test piece in Mo-B steel, aluminised ; ± 8·5 tons/sq. in., endurance 1,089 hours ; showing oxide penetration of coating. × 100

Fig. 10 (top right).—Fatigue test piece in Mo-V steel hot-dipped aluminium coated ; ± 10·5 tons/sq. in. ,endurance 449 hours ; showing oxide penetration of coating. × 100

Fig. 11 (middle left).—Fatigue test piece in Cr-Mo-V-W steel, hot-dipped aluminium coated ; ± 9·7 tons/sq. in., endurance 652 hours ; showing oxide penetration through coating. × 100

Fig. 12 (middle right).—Fatigue test piece in Mo-V steel, chromised ; ± 9·6 tons/sq. in., endurance 283 hours ; showing grain coarsening with strain markings in the grains near the surface. × 100

Fig. 13 (bottom left).—Fatigue test piece in Mo-B steel, chromised ; ± 9·5 tons/sq. in., endurance 275 hours ; showing general grain coarsening with strain markings in the grains near the surface. × 100

Fig. 14 (bottom right).—Fatigue test piece in En. 2A steel, chromised ; ± 2·94 tons/sq. in., endurance 640 hours ; showing wavy surface and strain markings in the centre surface grain. × 100

TABLE XI.—RELATIVE MERIT OF COATINGS IN RELATION TO CREEP BEHAVIOUR AT 650° C.

Steel	Stress (tons/sq. in.)	Duration (hr.)	Order of Merit	Remarks
En. 2A	0·5	1,000 4,000	C + HT; C; A; AD; UC C + HT; C; A; AD; UC	
	0·75	500 1,800	C + HT; A; C; AD; UC A; C + HT	
	1·0	200 600	A and C + HT; C; AD; UC A; C + HT; C	
Mo-B	2·0	1,000 3,300	AD; A; UC A; AD	Chromised very poor
	2·5	400 3,000	UC and AD; A A	
	3·0	500 1,500	A and AD; UC A	
Mo-V	2·0	1,000	AD; UC; A; C + HT; C	
	3·0	500 2,000	AD and UC; A; C + HT AD; UC	Chromised very poor
	4·0	500 2,000	AD and UC; A AD	Chromised andchromised + heat treatment very poor
Cr-Mo-V-W	3·0	1,000	C; C + HT; AD; UC; A	
	4·0	250 1,000	C; C + HT; AD; UC; A C; AD	
	6·0	200 500	C; C + HT; UC; AD C; UC	Aluminised very poor

Treatment Key :

A—Aluminised coating.
AD—Hot-dipped aluminium coating.
C—Chromised coating.
HT—Heat treatment.
UC—Uncoated.

since carbon diffusion is rapid in ferrite. In many cases the effect of the coating process can be almost entirely eliminated by re-heat treatment, but this is not the case with chromised coatings, because of the decarburisation effect. Indeed, re-heat treatment can aggravate the trouble unless care is taken to reduce the time during which the steel is held at a temperature just below the transformation point.

Where the life of a specimen under the combined effects of oxidation and creep or fatigue is determined mainly by oxidation resistance, the chromised coatings show up best, particularly for long endurances under low stress. The oxidation fatigue life at 650° C. of mild steel is improved by coating processes for exposures of 100 hours and over, and under creep conditions coating processes also show a marked advantage. At comparatively high creep or fatigue stresses the chromised coatings are slightly less effective than the aluminium coatings. This is mainly due to the influence of chromising on the mechanical properties, which becomes a more important factor than the effectiveness in combating oxidation. The effect is rather more marked in fatigue than in creep. This is probably mainly because the surface decarburisation caused by chromising results in a lower proof stress, and hence a greater surface strain in bending fatigue, and the nominal stresses under the test conditions are above the 0·5% proof stress.

TABLE XIII.—HARDNESS VARIATION OF CHROMISED Mo-B STEEL AFTER NORMALISING

Test Ref. No.	Description	Hardness (V.P.N.)	C in core (%)	
F 47	Normalised 980° C., ½ hr.	203	(0·135)	
F 48		209	—	
F 49		201	0·09 0·056	
F. 67		144	(0·093)	
F. 68		171	—	
F. 69		222	—	
FF 39		172/163*	—	
FF 40		172/161*	—	V.P.N. 165 at fracture
FF 41		213/152*	0·09–0·06*	V.P.N. 200 at fracture
FF 42		163/213*	—	V.P.N. 200 at fracture
FF 43		145	—	
FF 44		140/139*	—	
FF 45		170/176*	—	
F 67	Re-normalised 980° C., ½ hr.	141	—	
F 68		161	—	
FF 39		168	—	

* At other end of specimen.
Carbon percentages in parentheses refer to total for chromised coating and core.

The effects found—particularly with chromising—will be more exaggerated on sheet thinner than 12 s.w.g. and will tail off on thicker pieces. In fact, for quite thick sections, where the decarburised zone is a small fraction of the total, only grain refinement is necessary in order to have a satisfactory material from the strength and oxidation standpoints.

In the case of the aluminium coated specimens, the fatigue strength falls quite considerably with time of endurance under the oxidation fatigue conditions, although this fall is, of course, less marked than with uncoated specimens. This effect is due to oxidation—probably aggravated by inward diffusion of aluminium. With the chromised specimens, however, the fatigue strength changes relatively little when the fatigue endurance test is increased from 10 to 500 hours. This suggests that the determining factor in the case of chromised coatings will be whether the stress imposed is sufficient to crack the chromised coating or not, and provided the coating does not crack, it will confer almost indefinite oxidation resistance at this temperature. The very poor results of chromised coatings on Mo-B and Mo-V steels must be attributed to the very marked effects of the chromising process on the strength of the core material. This effect was less marked with the Cr-Mo-V-W steel, and could be still further minimised by special heat treatment.

This investigation has shown that hot-dipped aluminium coated Mo-V steel has creep properties superior to the relatively more oxidation resistant Cr-Mo-V-W steel in the uncoated state, with the 1% creep time at 4·0 tons/sq. in. increased from an average of 510 hours for two tests, to about 7,000 hours, and the rupture time

TABLE XII.—EFFECT OF COATINGS ON FATIGUE STRENGTH AT 650° C. (2,880 CYCLES/MIN.)

Coating Treatment	En. 2A Steel Nominal Endurance Stress (tons/sq. in.) for :			Mo-B Steel Nominal Endurance Stress (tons/sq. in.) for :			Mo-V Steel Nominal Endurance Stress (tons/sq. in.) for :					Cr-Mo-V-W Steel Nominal Endurance Stress (tons/sq. in.) for :		
	10 hr.	100 hr.	500 hr.	10 hr.	100 hr.	500 hr.	10 hr.	100 hr.	500 hr.	1,000 hr.	3,000 hr.	10 hr.	100 hr.	500 hr.
Uncoated	3·43	2·12	1·70	15·7	9·4	7·0	14·8	10·5	7·1	—	—	18·6	15·3	12·1
Hot-dipped aluminium	2·99	2·51	2·18	14·6	11·1	8·4	15·6	11·3	9·5	8·9	8·3	16·1	13·4	10·4
Aluminised	3·54*	3·04	2·76	10·2	9·1	8·7	17·5	14·3	12·1	11·0	9·4	14·0	11·1	9·1
Chromised	3·50*	3·21*	3·02*	9·8*	9·2*	8·9*†	10·6*	9·9*	9·4*†	—	—	8·9	8·8	8·7
Chromised + heat treatment	—	—	—	10·2	10·0	—	—	—	—	—	—	11·8	9·7	—
Chromised + special heat treatment (i.e. rapid heating to normalising temperature)	—	—	—	—	—	—	—	—	—	—	—	12·4	10·9	—

* Nominal stress exceeds 0·5% proof stress of core material. † Values extrapolated.

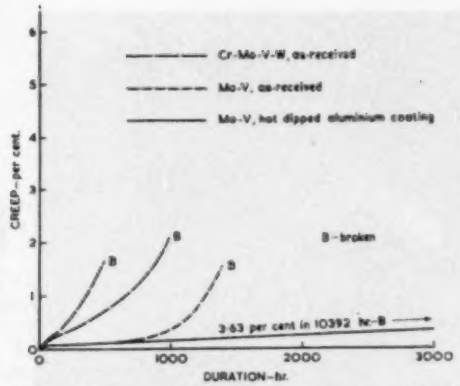

Fig. 15.—Comparison of creep curves of Mo-V and Cr-Mo-V-W steel tested at 4 tons/sq. in., at 650° C.

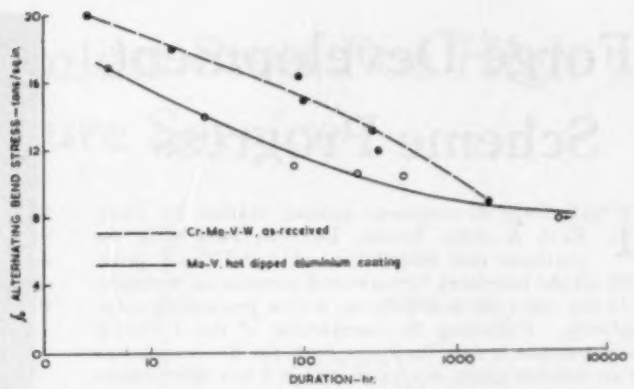

Fig. 16.—Comparison of fatigue curves for Mo-V and Cr-Mo-V-W steels tested at 650° C. (2,880 cycles/min).

from 502 or 981 hours, to 10,392 hours. This coating on Cr-Mo-V-W steel gave only a marginal improvement, increasing the rupture time to 1,240 hours. The fatigue endurance at high stresses for the aluminium dipped Mo-V steel are inferior, but the S : N curves show that, for endurance greater than 2,000 hours, it is equal to, or better than, that of the uncoated Cr-Mo-V-W steel. Figs. 15 and 16 show the relative behaviour of the two steels in creep and fatigue.

Comparing the creep results for the hot-dipped aluminium coated Mo-V steel, with the data reported by Glen (1955)[4] for uncoated steel of similar composition on specimens cut from 1 in. diameter bar, the results are shown to be much better on aluminium coated steel. In Glen's tests the time to rupture for 4·0 tons/sq. in. at 650° C. is about 3,400 hours and 0·3% creep in 400 hours, compared with our results of 10,392 and 2,500 hours, respectively, for the hot-dipped aluminium coated, and 1,395 and 940 hours respectively for the uncoated steel. The reduced rupture time for the uncoated Mo-V steel in the tests on the thin gauge sheet material, compared with the tests on bar is to be expected, since oxidation will be more serious with the thinner material.

In Table XIV, creep data for the hot-dipped aluminium coated Mo-V steel are compared with those for ferritic, stainless, and austenitic steels in bar form, extracted from a paper by Oliver and Harris (1952)[5]. The aluminium coated Mo-V steel is competitive at 650° C. with R.20, a 14% Cr, 19% W austenitic steel. The Mo-V steel ruptured in 10,000 hours at a stress of 4·0 tons/sq. in., and the R.20 steel at 4·5 tons/sq. in. Although no direct comparison of creep rates is possible, a qualitative evaluation can be made from the stress-minimum creep rate data. On this basis, the Mo-V steel is shown to be better than H.40 of approximately the same composition as the Cr-Mo-V-W steel investigated, and about equal to stainless steel H.46.

TABLE XIV.—COMPARISON OF CREEP DATA OF HOT-DIPPED ALUMINIUM-COATED Mo-V STEEL WITH FERRITIC AND AUSTENITIC STEELS

Steel	Description	Stress for Minimum Creep Rate of (tons/sq. in.)	(10⁻⁵/hr.)	Stress for Rupture in 10,000 hr. (tons/sq. in.)
Mo-V	Hot-dipped aluminium coating.	4·0	0·8	4·0
H.40	Ferritic–iron stainless: 0·23% C, 2·7% Cr, 0·5% Mo, 0·75% V, 0·5% W.	2·5	1·0	—
H.46	Ferritic–stainless: 0·2% C, 11% Cr, 0·5% Mo, 0·7% V, 0·15% Nb.	4·5	1·0	—
R.20	Austenitic: 0·15% C, 14% Cr, 19% W, 1·7% Nb.	6·5	1·0	4·5
G.18B	Austenitic: 0·4% C, 13% Ni, 13% Cr, 2% Mo, 2·5% W, 3% Nb, 10% Co.	11·0	1·0	11·8

Conclusions

Oxidation of Mo-V steel can be prevented by hot-dipping in aluminium without adversely affecting the creep and fatigue strengths at 650° C. Retention of the good creep properties makes it competitive with R.20, a 14% Cr, 19% W austenitic steel. The creep properties of the other steels tested were inferior to those of the Mo-V steel, and the coating process often reduced the intrinsic strength of the material, which offset the improvement in oxidation resistance.

The hot-dipped aluminium coating has been found to be an advantage for steels with poor oxidation resistance, e.g. mild steel and Mo-B and Mo-V low alloy steels. With the untempered mild steel and Mo-B steel, softening occurred at the process temperature, which reduced the creep and fatigue endurances at high stresses, but at lower stresses the creep rupture times and endurance in fatigue were increased due to the prevention of oxidation. Where oxidation resistance is inherently good, as with Cr-Mo-V-W steel, the added protection conferred by this coating was insufficient to compensate for the loss in strength.

Aluminising has been found to increase endurance at low fatigue stresses with mild steel and Mo-B steel, and at all fatigue stresses for the Mo-V steel.

Chromising, though providing a good oxidation resistant coating, unfortunately resulted in a marked loss in core strength through decarburisation and softening during the coating process. This could be partially offset by subsequent heat treatment. The fatigue endurance tended to be less affected at low stresses giving long endurances.

Acknowledgment

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Forge Development Scheme Progress

THE forge development scheme started by Thos. Firth & John Brown, Ltd., in 1953 with the purchase and installation of a 1,750-ton press, with all the necessary furnaces and accessories, including a 15-ton rail-type manipulator, is now proceeding satisfactorily. Following the completion of the 1,750-ton press scheme, a new shop was built for the installation of an 800-ton press, equipped with a 3-ton manipulator and with furnaces of the most modern design. This new addition to the forging capacity, which is being fitted with automatic precision control, already shows a tremendous improvement over the old type equipment.

The next stage in the development scheme is the installation of a new 4,000-ton press, and the acquisition of the premises of W. Griffiths & Sons, Ltd., in Brightside Lane has made possible the erection of the new press—due for operation by early 1961—whilst the old one is still working. The furnaces in this heavy press shop were of the old hand-fired type, and conversion to the most modern type of producer gas-fired furnaces will be completed by the time the press is ready for work. The extra space acquired as a result of the Griffiths transaction—amounting to some 5,500 sq. yd.—will allow extension of the 1,000 press bay, where the installation of three new 800-ton presses is planned.

800-ton Press

In the course of installing the 800-ton press, over 2,000 cu. yd. of earth and clay—weighing 3,000 tons—were excavated for the foundations of the press and furnaces. The press foundations incorporate about 1,200 tons of concrete, and the furnace foundations—which were taken down to a depth of 20 ft. in order to cover a 5-ft. diameter brick sewer from Brightside Lane—a further 2,000 tons.

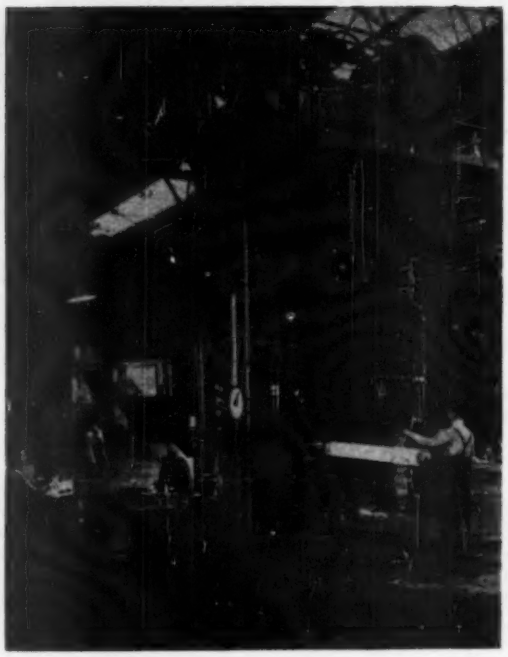
The press, which is 26 ft. overall in height, is capable of exerting a force of 800 tons through a ram operated by a 4,250 lb./sq. in. hydraulic system. The crosshead which carries the top tool is capable of exerting the full 800 tons force at a steady speed of 6–8 in./sec.; alternatively, it can be made to give light planishing strokes at the rate of 120/min. to finish the surface of the material under the press. Maximum daylight is 9 ft. and the working stroke 4 ft.

The press is controlled from a modern control desk with servo-operated valves, ensuring accurate and sensitive control. As a result of the finger-tip operation, physical fatigue of the operator is eliminated and the number of quick forging strokes can thus be considerably increased.

Power for the press is supplied by three throw horizontal pumps which are each driven by electric motors developing 550 h.p. and delivering 132 gal./min. at a pressure of 4,250 lb./sq. in. to a set of air-hydraulic bottles which form a reserve accumulator for the system.

Furnaces

The ingots or billets to be forged are heated to 1,150°–1,250° C. in six furnaces alongside the press. Two of these furnaces are heated by town's gas and the remainder by producer gas. A particular feature of these furnaces is the provision of automatic temperature and pressure control.



The 800 ton press in operation.

Handling

When the ingots or billets have been heated to the correct forging temperature, the bogie on which they are placed is withdrawn from the furnace and the material picked up by a 3-ton manipulator driven by its own diesel engine and weighing 20 tons. The manipulator takes the work-piece swiftly to the press, where the operator and manipulator driver work in conjunction under the direction of the forgeman to shape it into its final form.

If an extra-long forging is to be handled under the press, the manipulator is assisted by a 10-ton Semi-Goliath crane, which carries the end of the forging on the opposite side of the press, by means of turning-over gear operating a burden chain supporting the outer end of the forging. In this case the crane driver, press operator and manipulator driver have to work in unison under the direction of the forgeman, and it will be appreciated that the whole operation is essentially one of team-work.

The handling arrangements are completed by a 10-ton overhead electric crane which loads the furnaces and carries out general purpose duties in the shop.

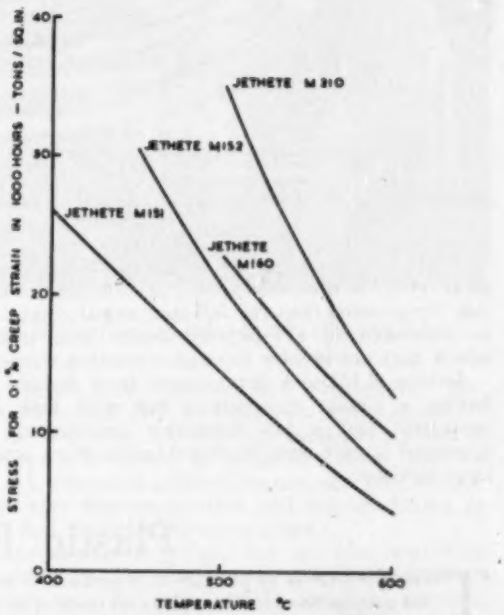
Despite the hot summer last year, it was found that working conditions were much more comfortable than those usually found in shops of this type because of the increased efficiency and design of the furnaces, leading to lower heat losses and, incidentally, making quite a contribution to a cleaner atmosphere.

High Strength Stainless Steel For High Temperature Service

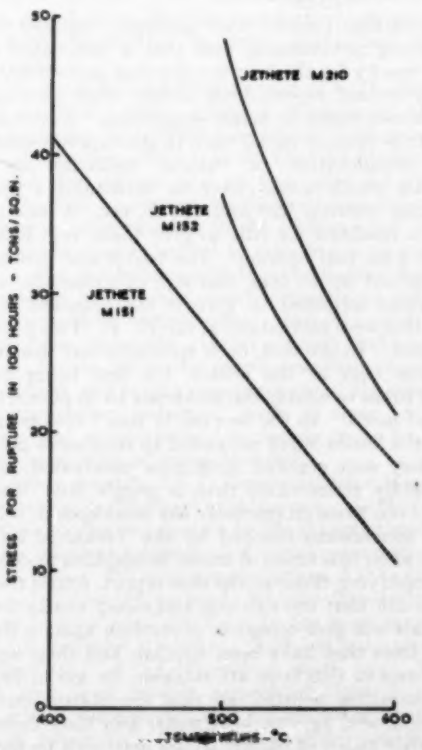
FOR some years, the research and development department of The United Steel Cos., Ltd., has been working in collaboration with Samuel Fox & Co., Ltd., a United Steel subsidiary, in the development of a range of high strength stainless steels for elevated temperature service.

This work, which has led to the introduction of the Jethete series of steels, was initiated because of the limitations of existing steels in providing adequate mechanical strength at elevated temperatures combined with good corrosion resistance. It is possible, for example, to obtain a wide variety of mechanical properties from low alloy steels, but they are insufficiently resistant to corrosion. Austenitic stainless steels of the 18% chromium, 8% nickel type have a good corrosion resistance but suffer from the major disadvantage of low mechanical strength. Similar considerations apply to fully ferritic steels, where ductility is also poor. By cold working, it is possible to improve the mechanical strength of both austenitic and fully ferritic stainless steels, but the higher properties cannot be retained at elevated temperatures.

High strength can be allied to corrosion resistance, however, by means of the transformable group of stainless steels. The most widely used steel in this group is the low carbon 12% chromium steel. This has a reasonable combination of mechanical properties, but is deficient in strength after tempering at 650° C. (which might be required after welding) and has relatively poor impact properties. Despite these limitations, this steel was selected as the starting point in the Jethete series.



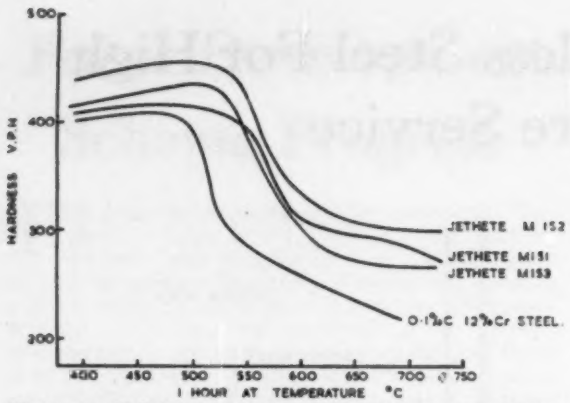
Stress required to give 0·1% creep strain in 1,000 hours at various temperatures.



Stress for rupture in 100 hours at various temperatures

One of the difficulties with the 12% chromium steel is that it is near the border line of structural stability. Chromium is a strong ferrite-forming element, and if appreciable amounts of ferrite are formed in the structure, the hardening effect is lost. By increasing the carbon content, ferrite formation can be prevented, but only at the expense of making the steel unsuitable for welding and reducing its impact resistance. To obtain improved strength, therefore, it is necessary to increase the tempering resistance by the addition of such elements as molybdenum and vanadium. As these elements are also strongly ferrite-forming, it is again necessary to balance the structure. For this reason, the Jethete series of steels are low-carbon 12% chromium-nickel steels, containing additions of molybdenum, vanadium, niobium and other elements as may be required to produce the desired properties.

Jethete M.151 is a low-carbon 12% Cr-Ni-Mo-V steel, in which the composition is so controlled that the structure is fully austenitic at solution and welding temperatures. On the other hand, the tempering resis-



Hardness (V.P.N.) after 1 hour at various temperatures.

tance is not so great as to prevent softening prior to fabrication. The major use of Jethete M.151 is in sheet form, where it must be capable of softening for fabrication by pressing, but the full mechanical properties can be recovered by a relatively simple heat treatment, which does not involve too high a solution temperature.

Jethete M.152 is a development from Jethete M.151, having a similar composition but with high impact properties and a low transition temperature. The improved impact level is advantageous when producing large sections.

While Jethete M.152 represents an appreciably increased strength level compared with the straight 12% chromium steels, there are applications where an intermediate strength will give satisfactory performance, and Jethete M.153 was introduced for this purpose. It is a 12% Cr-Ni-Mo composition, with higher impact properties and a slightly lower cost than Jethete M.152.

The high temperature properties of the 12% chromium steels are quite reasonable in the 400°–500° C. temperature range. A need arose for improving these properties, however, particularly for use in aircraft turbines, and Jethete M.160 was developed to meet this demand. This is a 12% Cr-Ni-Mo-V-Nb composition, the niobium addition providing the improved high temperature strength.

With further increases in aircraft engine temperatures, the strength of Jethete M.160 becomes inadequate, and accordingly Jethete M.210 was developed. This is a 12% Cr-Ni-Mo-Co-B composition, and the latest in the Jethete series, although development work continues towards the production of other high strength stainless steels with still further improved properties.

Much of this work has been undertaken initially in response to problems encountered in the field of jet aircraft and guided missiles, and the aircraft industry is a large user of the Jethete series of steels, but increasing interest is now being shown by other industries with analogous problems, and these steels are being employed in growing quantities for a variety of applications.

Plastic Foundry Goggles

THE application of plastics as a protective material for goggles used in foundries and tests of its ability to withstand high impact from hot or cold solid particles, are described in the second Report of the Joint Advisory Committee on Foundry Goggles which was presented recently to the Chief Inspector of Factories.

The report incorporates the investigations on this subject by the Technical Sub-Committee which designed constructed and used a new type of rig for a series of tests, and found certain materials which withstood this testing. Preliminary work was also done on certain opthalmalogical aspects of the selected materials, and there is good reason to believe that the materials will satisfy the British Standards requirements.

The Technical Sub-Committee have now been asked to proceed with the third phase of their work, and this is already in progress. This work involves the design and construction of another testing rig on which complete goggles, spectacles or face screens can be tested so that the performance of the actual articles worn can be judged.

According to the report, there is now every reason for the makers and users of all forms of eye protection, for use in foundries in particular, and in industry generally, to be aware of the findings of the Sub-Committee and for makers to proceed at once with such research and development in co-operation with the Advisory Committee to ensure early commercial production of eye protection equipment on the basis of the information now available.

In their first report, the Committee indicated that toughened or laminated glass should be discarded as a protective material in any foundry work, where eye protection had to be adequate to withstand molten splashes or impact from hot or cold solid particles. They concluded that plastics were generally superior to glass in resisting penetration, and that a laminated plastic goggle was by far the best for physical protection.

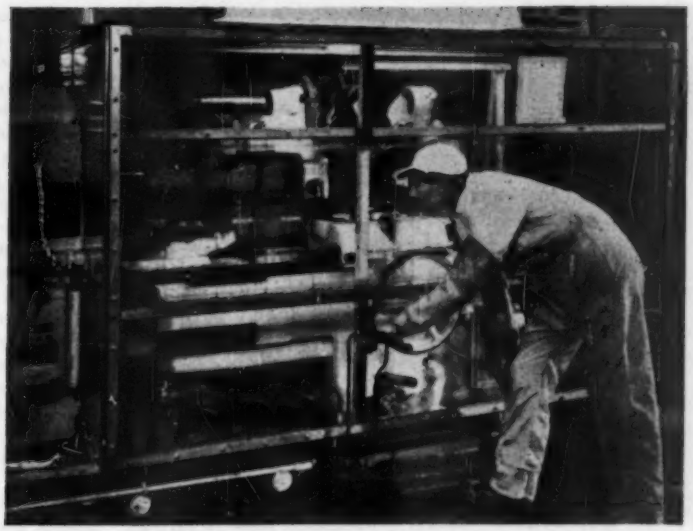
Their second report deals chiefly with plastics from which lenses might be made, suggesting " double lenses " against the impact values used in the experimental work. After consideration of various methods of testing materials which would have to withstand a projectile travelling between 330 and 400 ft./sec., it was decided to use a modified air rifle to give these velocities when using a ½ in. ball bearing. The barrel and loading plug were opened up to take this size of projectile, and the mechanism adjusted to give it the required velocity.

All tests were carried out at 65–75° F. Two procedures were used. In the first, each specimen was submitted to one blow only at the centre, the test being repeated several times to enable the materials to be placed in some order of merit. In the second, it was " test to destruction," the lenses being subjected to successive projectiles until they were cracked, broken or penetrated, although it is hardly conceivable that a goggle lens would be struck even twice on precisely the same spot in service.

The conclusions reached by the Technical Sub-Committee, after this series of trials, in addition to confirming and amplifying those in the first report, found that there is no doubt that the existing and easily available plastic materials will give complete protection against the fairly severe tests that have been applied, and their opinion is that lenses of this type are suitable for use in foundries. The committee pointed out that the plastic lenses were also successful against heat tests, and they commented that other types of plastic lenses may well be developed in the future.

Europe's First Wrought Beryllium Plant

I.C.I. Developments in the New Metals Field



Ingots of beryllium are reduced to chips in this swarfing lathe.

KYNOCH WORKS, Witton, is almost 100 years old. Starting life as a percussion cap factory and expanding to take in cartridge manufacture, the works was over thirty years old when its first metal mill was laid down. Its job was to produce rolled strip in a particular copper alloy—cartridge brass. As the metal side of the business expanded to cover other wrought forms, such as rod, tube and wire, more and more emphasis was laid on the development of copper alloys with specific properties to meet specialised service requirements.

By 1926, when Kynoch became part of I.C.I., the busy—if comparatively small—research department at Witton was no longer concerned solely with routine process control. Part of its effort was devoted to fundamental research on new alloys, and on new uses for existing alloys. The first important break-away from copper as the basic raw material came in the 1930's, when I.C.I.'s metal interests were extended to take in aluminium and its alloys. But it was the surge of technological development initiated by the war which emphasised the need for a far-reaching metallurgical research effort. In particular, the demands of the aircraft industry for structural metals with ever more exacting properties, and the urgent and taxing requirements of the emerging nuclear engineering industry, made it clear to metal producers that revolutionary materials must be made available—and with all possible speed.

For various reasons, I.C.I. Metals Division was well-placed to play a leading part in this quest. As the largest producer of non-ferrous metals in the Commonwealth, it had at its disposal research and development facilities second to none. Its sister-organisation, I.C.I. General Chemicals Division, had already laid the foundations for important technological advances in the most promising new aircraft material, titanium. And—in some ways the most significant of all—technical staff from Metals Division had been closely associated right from the beginning with the harnessing of atomic energy, and were directly in touch with all aspects of development.

In 1942, the first extruded uranium rod ever to be produced in the U.K. was made in a Witton mill. Britain's first titanium melting plant was commissioned at Witton in 1955; the first titanium fabrication plant at Waunarlwydd, Swansea, in 1958—the same year in which I.C.I. zirconium achieved commercial production; and 1959 saw the construction and commissioning of Europe's first wrought beryllium plant.

Less spectacular in scope, but no less rewarding technically, is the Division's work, still in the development stage, on three other metals—hafnium, niobium and vanadium—each of which promises to fulfil a highly specialised need in the nuclear reactors of the future.

Titanium

British titanium is six years old and its American counterpart but a few years older. Although the metal was discovered and recognised as an unusually strong metal over 150 years ago, it was not until 1949 that an economic large-scale process, yielding metal of adequate quality, was evolved by W. J. Kroll, working for the U.S. Bureau of Mines. The Kroll process is based on the reaction of titanium tetrachloride with the metal magnesium to yield titanium metal and magnesium chloride which is removed by vacuum distillation. I.C.I. General Chemicals Division built a Kroll plant with a capacity of 12 tons a year in 1951 to give Metals Division experience in melting and fabrication. This was replaced three years later by a 100 ton capacity plant of the Kroll type, but in the meantime General Chemicals Division continued the efforts to develop a cheaper and better method based on sodium which would yield a by-product—sodium chloride—which could be separated by a relatively cheap process. Teething troubles overcome, a full-scale sodium reduction plant was commissioned at Wilton Works, near Middlesbrough, in 1955, with the object of producing 1,500 tons a year of dull grey granules of raw metallic titanium.

The high melting point and reactivity of titanium prohibit normal melting and casting methods of producing massive titanium, and the technique adopted involves consumable electrode arc melting *in vacuo*.

The granules of raw titanium, sometimes mixed with other powdered metals to make alloys, are pressed into briquettes and welded together to form a 12 ft. long electrode weighing almost a ton. The electrode is suspended from the top of the furnace and a small quantity of raw titanium placed in the base of the water-cooled copper crucible and the furnace evacuated. An arc is then struck between the electrode and the titanium in the crucible and the whole electrode is slowly melted to form an ingot. To ensure homogeneity, the ingot is remelted by the same process into a larger diameter crucible. When the original Witton plant was commissioned in 1955, the weight of ingot was limited to 400 lb., and eighteen furnaces were needed for an annual output of 1,500 tons. Today, 2,000 tons a year can be produced, in ingots weighing 2,100 or 4,200 lb., by just three furnaces.

Once in ingot form, conventional metal-working techniques can be used, provided that attention is paid to titanium's inherent characteristics, such as oxidation behaviour, low rate of work hardening, and tendency to gall on sliding contact. After checking for flaws by ultrasonic testing, the ingots are forged into flat slab or round billet and shotblasted or machined prior to further working. The bulk of the Witton output goes to the fabricating plant at Waunarlwydd, South Wales, for conversion on specially adapted plant, to rod, sheet and tube. Other wrought forms—wire and extruded sections—are processed on plant normally used for conventional non-ferrous alloys.

Progress in the titanium field has largely been the outcome of the need of the aircraft industry for a light alloy which would withstand the strains and exigencies imposed by ultra-high-speed flight. Titanium has a high strength/weight ratio, and its strength is retained at temperatures higher than are considered safe for aluminium alloys. The fatigue ratio of titanium and its alloys is also higher than that of most non-ferrous metals. Six grades of commercially pure titanium are featured in the I.C.I. range, and higher strength alloys are available for stressed applications.

The outstanding resistance to corrosion and erosion by a wide range of aggressive media has aroused the interest of chemical engineers in titanium, and it is being used for complete components and for lining vessels and larger components. Titanium is also finding application, with an extremely thin coating of platinum, as anodes in electrolyte cells and for the cathodic protection of marine structures and chemical plant. In a different field, its immunity to attack by body fluids has led to its replacing some of the stainless steels and cobalt alloys for making surgical implants.

In the nuclear field, titanium and some of its alloys, having an extremely short " half-life," are particularly suitable for certain components in nuclear reactors, such as handling gear and control rod sheaths.

Zirconium

The story of zirconium runs parallel with that of titanium in its early chapters and it remained " on the shelf " for nearly 150 years. The advent of nuclear engineering initiated a re-evaluation of the less common metals. The first to emerge as a practical commercial proposition was zirconium which—from a nuclear engineering viewpoint—has the valuable properties of low neutron absorption, good mechanical strength at room and moderately elevated temperatures, and compatibility with uranium fuel up to a high temperature. Zirconium has chemical and physical properties similar to those of titanium and, like titanium, it is hardened by even slight traces of non-metallic impurities such as oxygen and nitrogen.

The silicate zircon, which is found in beach sands, is widely distributed throughout the world, and raw zirconium in sponge form is extracted from these sands by chemical processes generally similar to those used to extract titanium. Unfortunately, all zircon deposits contain 1–2% hafnium, a sister metal which readily absorbs neutrons. Where neutron absorption is not critical, hafnium-bearing sponge can be used, as it does not affect the mechanical properties, but the hafnium must be removed in the course of the extraction process if " reactor grade " material is required.

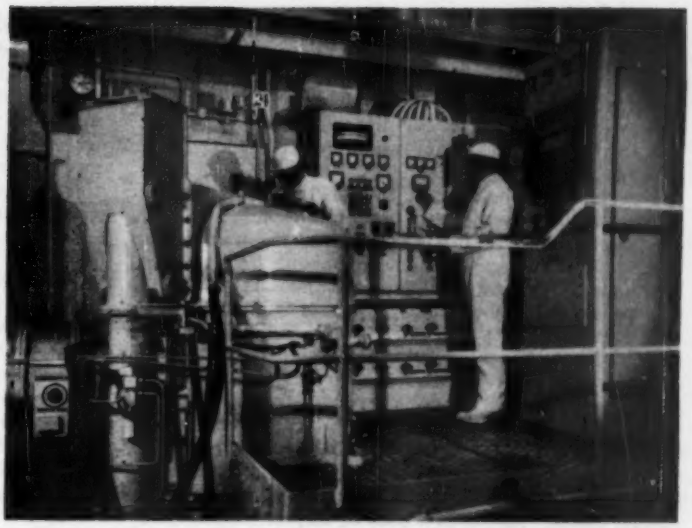
The nine years' research, development and production experience with titanium stood I.C.I. Metals Division in good stead when work on zirconium began. Using melting methods similar to those for titanium, production began in 1958, and ingots weighing 10 cwt. are regularly produced in Europe's largest zirconium melting plant; if required, 3 ton ingots can be made in this plant. Ingots are converted into wrought forms—strip, sheet, plate, rod, tube and wire—by conventional processes, though precautions must be taken during hot working and annealing to avoid contamination, particularly by nitrogen, which impairs corrosion resistance. For thin sections, vacuum annealing methods are preferred.

The main uses of zirconium are in nuclear engineering, and zirconium alloys with outstanding corrosion resistance to water and steam at high temperature and pressure have been developed for fuel sheathing and core components in pressurised water and boiling water reactors. Zirconium alloys resistant to corrosion by carbon dioxide have also been developed—notably in the research laboratories of Metropolitan-Vickers Electrical Co., Ltd.—and fabricated into fuel element supports, tubes for control devices, etc. The heavy water-moderated gas-cooled reactor may require zirconium alloy for pressure tubes or calandria systems, and in the sodium-cooled graphite-moderated reactor system it is necessary to clad the graphite with zirconium to prevent sodium attack. In the Dounreay experimental fast reactor, zirconium is used as a " getter " for the sodium coolant.

Outside nuclear engineering, zirconium has few uses at present, mostly concerned with its corrosion-resistance, which is superior to that of titanium in respect of certain media, and inferior towards others. A somewhat surprising use is in photographic flash bulbs for colour photography.

Beryllium

In some ways, beryllium is not a new metal. It has been used for many years as an additive in the production of beryllium-copper, a strong alloy widely used in the electrical industry. What is new is the relatively large-scale production of pure beryllium in wrought forms. Like zirconium, this is a metal which submits very reluctantly to the demands of the metal manufacturer. It is not particularly abundant—it ranks thirty-second among the elements—and extraction from the ore, the semi-precious stone beryl, is a laborious and costly process; special techniques are necessary to overcome technical difficulties at every stage of production and to eliminate the toxic hazard which powdered beryllium and its salts may present.



Beryllium powder, produced by reducing the cast ingot, is consolidated in a sintering furnace prior to extrusion

In these circumstances, only the recognition of wrought beryllium as a potentially very desirable metal would have triggered off the long and expensive research effort needed to bring it into commercial production. Such a demand arose in this country when forward planning by the United Kingdom Atomic Energy Authority revealed the need for a new fuel sheathing material.

Metals used for fuel cans must fulfil very exacting requirements. In all reactor operating conditions, the can must safely contain the fuel and dangerous radioactive fission products; be compatible with both the fuel and the coolant; be as "transparent" as possible to neutrons, the life blood of the reactor; and allow efficient transfer of heat to the coolant. In current gas-cooled reactors, special magnesium alloys provided the answer.

But the next steps in improving the efficiency of gas-cooled reactors (and in producing cheaper power) involve operating at much higher temperatures—perhaps up to 600° C. against the 450–470° C. of current reactors of this type. At these temperatures magnesium alloys are not suitable, so a metal was needed which not only had all the useful properties of magnesium alloys, but retained them effectively at much higher temperatures. Of all the metals evaluated, beryllium was much the most promising, and the U.K.A.E.A. therefore specified this metal for use as fuel sheathing in the experimental advanced gas-cooled reactor.

Largely because of its exceptional research and development resources and long experience of nuclear engineering requirements, I.C.I. Metals Division was entrusted with the task of producing the wrought beryllium for these cans.

Beryllium has many useful properties. From a nuclear viewpoint, the most important are high strength at elevated temperatures, good corrosion resistance to carbon dioxide, and a very low neutron absorption cross-section—less than half that of magnesium, the most effective neutron-transmitter in common use. In addition, it has a very low density, a high elastic modulus and good thermal conductivity.

On the debit side of the account, it has poor ductility, which at the moment can only be improved by employing powder metallurgy techniques during early stages of processing. This complicates production both directly and indirectly, because powdered beryllium can affect the lungs if inhaled in excessive amounts, and special precautions must be taken to ensure that personnel are not exposed to this risk. The problem is essentially one of dust control. The safe level of atmospheric contamination adopted for the Witton plant, determined as a result of more than ten years' experience in U.S. and U.K.A.E.A. plants, is 2μg./cu. m. This is equivalent in volume to half a grain of sugar in an average-sized living room. No case of beryllium poisoning has ever been reported in personnel working within these limits. The level of contamination permitted in air extracted from the plant—0·01 μg./cu. m.—is many times less than the amount present in any domestic chimney.

Details of the physical and mechanical properties of beryllium are given in Table I, together with comparative data for other structural metals.

Beryl, the principal source of beryllium, is an aluminium beryllium silicate generally yielding about 3½% beryllium. No economic concentration process has yet been developed and the beryl crystals are sorted by hand. Metallic beryllium is separated by a three-stage extraction process. The ore is converted into a chemical

TABLE I.—PHYSICAL PROPERTIES OF BERYLLIUM AND OTHER METALS

	Be	Mg	Zr	Al	Fe	Cu	Ti
Atomic number	4	12	40	13	26	29	22
Atomic weight	9·02	24·32	91·2	26·97	55·85	63·54	47·90
Melting point (° C.)	1283	650	1852	660	1535	1084	1660
Density (g./cm.³)	1·85	1·74	6·51	2·70	7·86	8·94	4·51
(lb./in.³)	0·066	0·063	0·235	0·097	0·283	0·322	0·163
Thermal conductivity at 20°C. (cal./cm./° C./sec.)	0·38	0·35	0·05	0·50	0·17	0·92	0·04
Thermal neutron absorption cross-section—							
Microscopic (barn*/atom)	0·009	0·059	0·180	0·215	2·53	3·69	5·6
Macroscopic (cm.⁻¹)	0·0012	0·003	0·008	0·014	0·215	0·313	0·238
Macroscopic comparison (Be as 1)	1	2·5	7	12	180	260	273
Specific heat (0–100° C.) (cal./g./° C.)	0·42	0·245	0·066	0·211	0·109	0·093	0·126
Coefficient of linear expansion (0–100° C.) (× 10⁻⁶ per ° C.)	11·54	25·8	5·8	23·8	11·9	16·4	8·9
Modulus of elasticity (× 10³ lb./in.²)	43	6·5	13·7	9·7	29	17·5	15

* 1 barn = 10^{-24} cm.²

compound, beryllium hydroxide, and this in turn into beryllium fluoride or beryllium chloride. Pure metal is extracted either by reacting the fluoride with magnesium, which produces "pebbles," or by electrolysis of a mixture of beryllium and sodium chloride, which yields "flake." The I.C.I. plant uses as its raw material imported flake and pebble beryllium.

This plant is the first in Europe to be designed for processing large quantities of beryllium from raw material to wrought product. It will operate as a research production unit with an initial output of about 7 tons a year. The plant incorporates all the recommendations on the safe processing of beryllium based on U.K.A.E.A. and U.S. experience. It is a single-storey building, broadly divided into contact areas, where beryllium is handled, and non-contact areas free from beryllium.

The production area, laboratories and ventilation bay —all contact areas—are designed to simplify dust control. There are no windows and the incoming air, filtered and heated, is changed every three minutes and extracted through machine enclosures, glove boxes and special ducts. About 200 tons of air are moved every hour and passed through absolute filters before being discharged from the 150 ft. chimney. Sealing compound is used between all wall and ceiling joints, and a negative pressure is created inside the building by the ventilation system. This ensures that all contact air follows the prescribed route through the exhaust filters, keeping adjacent areas free from possible contamination. Flat ledges are kept to a minimum and, to facilitate cleaning, floors are curved to the walls and all surfaces are smooth and painted.

Plant rooms housing electrical and other ancillary production equipment, as well as stores, despatch areas, changing rooms, loft and mess-room, are all non-contact areas. The building is normally entered through the amenities area, which comprises reception, changing rooms, clothing store and toilet facilities. Personnel are supplied with a complete set of clean clothing at the beginning of each shift and shower on leaving the contact area.

Unlike most finely divided metallic powders, beryllium is not pyrophoric. Since, however, a fire in the plant might cause interference with dust control routines, constructional materials and finishes throughout have been selected to reduce fire risk to a minimum. The use of wood has been completely avoided; all doors, door frames, chairs, tables, etc., are made of steel—a safeguard only possible where a plant has been designed from the drawing board with this object in mind.

In addition to all these precautions, air samples (amounting to some 3,000 a week) are taken at regular intervals both inside and outside the plant. These samples are analysed to ensure that the strictest standards of purity are maintained, and that there is no possible hazard to plant operators or to the general population.

Two factors complicate the consolidation of beryllium flake. First, properties of the wrought metal are adversely affected by impurities present in the raw material, so that refining in a vacuum induction melting furnace is an essential preliminary. Second, even vacuum-cast beryllium has a very large grain size and is extremely brittle. To produce metal with superior mechanical properties, particularly in regard to ductility, powder metallurgy techniques must be employed. For this reason, the cast ingot is machined to swarf, which in turn is ground to fine powder.

The powder is then packed into graphite moulds and sintered at high temperature under vacuum. Solid compacts produced in this way are either machined to finished size or prepared for further processing. Rod and tube are produced by extrusion, particular care being taken to avoid seizing in the dies. This is achieved by plating the extrusion slug or enclosing it in a protective mild steel sheath.

Careful design of equipment handling powdered beryllium ensures that air contamination is kept within the prescribed limit. Suction pipes working with a velocity of 10,000 ft./min. are provided immediately adjacent to cutting tools or other points of dust generation, and all machining operations are performed inside glove boxes from which air is automatically withdrawn. Special protective clothing and face masks are used

High purity of both raw material and metal is ensured during processing by frequent analysis and radiography.

during commissioning and for certain maintenance operations, but they will not normally be necessary for routine processes.

Just as contact between personnel and powdered beryllium must be avoided as a safeguard to human health, so contact between the metal and contaminating elements must be avoided to safeguard the quality of the metal. The finished product must conform to a most exacting specification, limiting contamination by certain elements to a fraction of a part per million. In these circumstances, the composition of lubricants and cleaning materials, of the detergents used to launder clothing and even of the soap used by employees, may be critical. This almost clinical attention to detail typifies the completely fresh approach needed to produce new metals.

Apart from small quantities used in X-ray windows, the main outlet for beryllium has so far been for reflectors in atomic reactors. In the experimental advanced gas-cooled reactor being built by U.K.A.E.A. it will be used not only for fuel cans but also for ancillary equipment.

Outside the nuclear engineering field, beryllium is potentially interesting to aircraft engineers because of its combination of low density and high elastic modulus; reports indicate that it has already been used in the United States for components in high-speed aircraft, guided missiles and guidance systems. The technical and economic obstacles in the way of large-scale utilisation are, however, considerable. Because of its comparative scarcity and the elaborate techniques involved at all stages of production, beryllium is inevitably an expensive metal. Raw beryllium costs about £20/lb., and the present quoted world price for wrought beryllium is about £160/lb. Even at this level (less than half the price of platinum), use of beryllium can be justified where its properties offer unique technical advantages. As increasing demand and/or technological improvements reduce the price, its potential as an important new engineering material will be more clearly seen.

Newer Metals

Although the research department at Witton has been concerned for many years with research into new alloys, it has only recently set up a new metals section, the nucleus of which was set up for pioneer work on titanium and zirconium. Today, the section is much concerned with metals likely to play an important part in nuclear engineering.

The evaluation procedure to which new metals are subjected is prolonged and comprehensive. However dazzling its natural properties, a metal is useless as a structural material unless it can be consolidated into ingots, processed into wrought forms such as sheet, rod and tube, and finally machined or otherwise fabricated into the shape required. Moreover, processing must be practicable not only at the level of laboratory experiments, but on the scale and in the conditions of everyday commercial production.

Evaluation is carried out initially on very small buttons, weighing perhaps as little as half an ounce, produced in special miniature furnaces. Some metals (e.g. titanium and niobium) will only develop homogeneous structures if heated over very long periods—weeks or even months. At the other extreme, they may undergo undesirable structural changes if allowed to cool naturally, so special treatment in vacuum quenching furnaces may be needed before the specimen is ready for microscopic examination.

When results are satisfactory, progressively larger melts are processed in various types of vacuum furnace. The arc melting laboratory has facilities for producing buttons weighing up to 100 g. and ingots weighing from 5 lb. to 300 lb. At every stage, the consolidated metal is subjected to exhaustive chemical, physical and mechanical testing, its deformation characteristics are studied so that suitable rolling, extrusion and drawing techniques can be established, and close attention is paid to any problems relating to machining and jointing the wrought product.

Typical of the metals now undergoing evaluation in this way are three of particular interest to the nuclear engineer :—

Hafnium—Hafnium, which always occurs in association with zirconium, has many of the characteristics of its sister-metal, including good mechanical strength and corrosion resistance. Unlike zirconium, however, it very readily absorbs neutrons. This feature, which makes it unsuitable as a fuel sheathing material, can be turned to good account in applications where a high rate of neutron absorption is an advantage, notably in the construction of control rods for pressurised water-cooled reactors. Supplies of raw hafnium of suitable quality are restricted, but good progress has already been made in the development of arc melting and fabrication techniques.

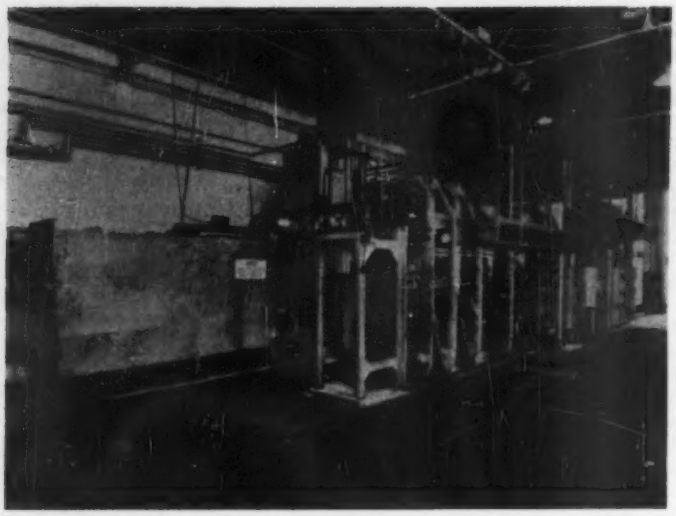
Niobium and Vanadium—These metals have useful properties, notably excellent ductility, and are interesting to the nuclear engineer becasue of their compatibility with uranium and with liquid metals. For this reason, they are already being used experimentally as sheathing materials in the liquid-metal cooled fast reactor at Dounreay. Outside the nuclear field, niobium alloys have considerable possibilities for aircraft gas turbine blades. It is reported that in the U.S. niobium alloys with excellent oxidation resistance up to 1,230° C. have been developed and that forged niobium alloy blades are being used in a development engine. Simple wrought forms such as rod, sheet and tubes are now being made in I.C.I. research department from arc-melted material.

Coal Gasification Plant Contract

THE West Midlands Gas Board have awarded the contract for a high pressure coal gasification plant on a new site at Coleshill, Warwickshire, to Woodall-Duckham Construction Co., Ltd. The installation will include tonnage oxygen plants, Lurgi-type complete gasification generators, and extensive ancillary plants for gas treatment and enrichment, by-product recovery, effluent treatment, and coal and ash handling. The gas manufacturing capacity will be 40 million cubic feet daily and provision will be made for future extension in two stages to 80 million cubic feet and 120 million cubic feet daily. The generators are designed to gasify low rank, small coals from the Midlands coalfields. The work to be carried out by Woodall-Duckham commences with the green site and continues to full gas production from the installation in 1963.

THE International Furnace Equipment Co., Ltd. has received an order from The Ford Motor Co., Ltd., Dagenham, for a further continuous automatic gas carburising furnace—making a total of four in all—for installation in their transmission gear heat treatment section.

Automatic Hardening and Tempering of Carbine Barrel Forgings



General view of the front of the furnace : on the left is the pusher mechanism for the hardening section, and on the right the tempering furnace line.

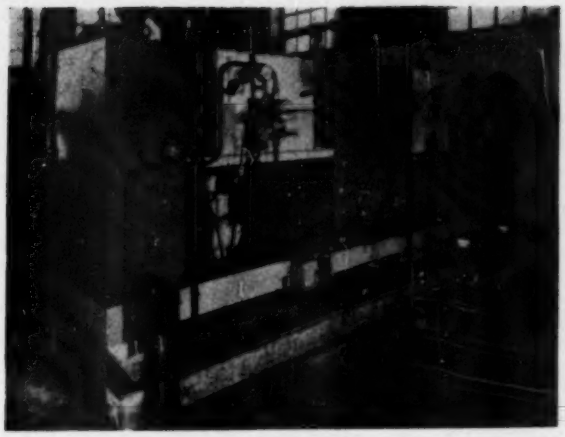
EQUIPMENT used in small arms manufacture should make possible high production, be economical in labour and materials, and be simple in operation. The general streamlining of the armed forces in recent years and the standardisation of a number of weapons amongst the NATO powers have tended to reinforce these points. High production units have been set up in a number of ordnance factories employing the latest techniques and equipment. This has occurred on a large scale at the Royal Ordnance Factory, Fazakerley.

One interesting unit which has recently been installed there is a fully automatic continuous hardening and tempering furnace for the treatment of carbine barrel forgings. Previously, barrel forgings had been treated in gas-fired batch furnaces, served by a single traversing charging machine. Hardening, tempering and quenching had been separate operations, each one requiring the use of the charging machine. The forgings had previously been loaded horizontally, and this naturally led to an appreciable percentage suffering some measure of distortion during the heat treatment. This has now been substantially reduced.

The new furnace, which was designed and built by G.W.B. Furnaces, Ltd., is almost completely automatic in operation. It requires only one operator to supervise control, loading and unloading. The different sections of the furnace are linked by conveyors and the separate operations are carried out automatically ; thus, high productivity is obtained and supervision is reduced to a minimum. Refinements in the actual heat treatment and the use of special suspension jigs for the forgings produce a much better finish, and effect a considerable reduction in the quantity of rejected material. The unit is flexible in that, if required, the hardening and tempering sections of the furnace can be worked separately and the various sequences of the furnace can be adapted to suit changing requirements.

The complete installation comprises one pusher-type hardening furnace with an automatic quench and a degreasing unit, together with a pusher-type tempering furnace, also equipped with quenching and degreasing plant. Both the quench units are equipped with oil circulating pumps and oil coolers, and a G.W.B. protective atmosphere plant is employed for use with the hardening furnace. These items of equipment are arranged in the form of a ' U ', the hardening furnace and its quench tank and degreaser forming the first leg, the bottom of the ' U ' being formed by an electrically driven cross-traversing track, and the other leg by the tempering furnace together with quenching and degreasing units. A further cross-traversing conveyor links the end of the tempering line with the entry to the hardening furnace.

Barrels are suspended from specially constructed heat resisting jigs, each capable of carrying eight forgings, loading and unloading being effected whilst the carriers are on the final cross-traversing track conveyor : the loading sequence is approximately 7½ min. Forgings to be treated are conveyed automatically under the pivot head of the hardening furnace hydraulic pusher, of overhead mounted design, which conveys the carriers separately into the hardening furnace. The effective dimensions of the hardening furnace are : heated length 13 ft. 4 in., width 9 in., height 3 ft. 3 in. A rating of 120 kW. is included in two independent automatically controlled zones, giving a maximum temperature of 900° C. Normal operating temperature is 850° C., with a soaking time of 1–1½ hr., and the unit was designed for a nominal power consumption of 73 kW./hr. at 850° C. Robustly constructed, with a gas-tight casing, the furnace is well insulated to minimise body losses. Two rows of heat-resisting skid rails support the charge carriers during their passage through the furnace. Heavy section 80–20 nickel-chromium strip heating elements are arranged on the side walls of the chamber, supported by a special hook suspension method. At each end of the furnace is an electrically-operated fully-insulated counterbalanced door. Fitted to the base of the entrance door



G.W.B. endothermic burnt town's gas plant complete with silica gel drying unit.

is a unit section of skid rails used for alignment purposes during charging operations.

A gas-lock chamber is situated at the entrance of the hardening furnace, whilst at the exit is fitted a gas-tight quenching hood, the bottom edges of which are immersed below the level of the quenching medium. In addition to preserving the protective atmosphere, the quenching hood also ensures that the charge ready for immersion is completely free from the cooling effect of draughts, and tends to produce constant uniform quenching temperature.

As the pusher propels the carriers through the furnace, an extractor gear is timed to remove the carrier from the furnace chamber on to the platform of a quenching hoist. The extractor gear comprises a steel frame sited immediately above the quench tank, and the extractor head is provided with a pivoted pawl. Immediately the extractor gear has removed the charge carrier from the furnace and deposited it on the quench hoist platform, the platform automatically lowers and places the carrier on to the quench conveyor, which conveys the charge through the quenching medium and also through the degreasing unit. The approximate dimensions of the quench tank are 10 ft. long × 3 ft. 3 in. wide × 4 ft. deep.

In the gas heated degreasing unit, the barrels are sprayed from a battery of fixed jets which are supplied with degreasing solution from a motorised pumping unit. In the base of the degreaser is situated a gas heated coil which controls the temperature of the solution by means of a 4 in. dial thermometer.

Further extractor gear, similar in construction to that previously mentioned, removes the charge carrier from the quench conveyor and transfers it on to a traversing conveyor ; by this arrangement, the charge carriers are conveyed into the tempering furnace line. The traversing conveyor is fitted with tee-section attachments to accommodate charge carriers. On reaching the tempering furnace line, the charge carrier is pushed from the traversing conveyor into the tempering furnace by a second pusher gear. The effective dimensions of the tempering furnace are : heated length 20 ft., width 9 in., height 3 ft. 3 in. With a rating of 90 kW. in three independent automatically controlled zones, the unit has a maximum temperature of 650° C. Generally, the tempering furnace is similar in construction to the hardening unit, but since no protective atmosphere is employed, the fittings connected with this process are not present. Different types of forgings are soaked for periods ranging from 1½ to 3 hr. at temperatures up to 650° C. Since these treatments are in the lower temperature ranges, some form of air circulation is necessary to provide efficient distribution of the heat. To this effect, four air circulating fans are situated in the furnace roof, and baffles of heat-resisting alloy are specially situated to give directional air flow over the heating elements and through the working space. Quenching and degreasing arrangements, together with the extractor and conveyor systems, are similar to those in the hardening furnace line, so that a continuous conveyor system is formed, linking all operations.

Each of the furnaces is provided with its own set of electrical equipment, all of G.W.B. manufacture. The switchgear comprises two iron-clad contactor cubicles, one for each furnace, and a totally enclosed motor panel housing 60 motor contactors for the various pusher, extractor, hoist and conveyor drives. Automatic temperature control for both furnaces is provided by a common instrument control panel. A complete sequence of operations for the installation is carried out automatically, and all the necessary limit switches and similar interlocks are controlled from a master sequence time switch in the instrument control panel. The protective atmosphere plant is a standard G.W.B. burnt town's gas exothermic unit having a capacity of 1,000 cu. ft./hr., and linked with a G.W.B. silica gel gas drying plant.

Vacuum Furnace Order

The General Electric Co., Ltd., in association with Vacuum Industrial Applications, Ltd., has received an order for the supply of a vacuum melting furnace to the British Iron and Steel Research Association for use in their Sheffield laboratories. The furnace has a melting capacity of 56 lb. and is to be used for research into the vacuum melting and casting of ferrous metals. The working pressure of the furnace is 1 micron Hg., and it is designed for a working temperature of 1,700° C. ; the charge is poured into the moulds by tilting the crucible. The 24-in. diameter furnace chamber is horizontal to provide ample working space and to permit easy cleaning of the inner surface. Within the chamber are dip thermocouples for temperature measurement, and also six tipping buckets for adding alloying metals to the molten charge. The chamber is evacuated by means of a two-stage pumping system comprising a 10 in. oil booster-diffusion pump backed by a gas-ballasted rotary pump. The pumping speed of this combination is high enough to maintain the chamber pressure under conditions of severe outgassing. The charge is induction heated and power for the furnace is supplied by a 10 kc/s. motor-alternator.

Magnesium Price Rise

Alcan (U.K.) Ltd., have announced that, as from 1st January, 1960, their price for primary magnesium in 20 lb. ingots of 99·8% minimum purity is 2s. 2½d. per lb. delivered customer's works in the United Kingdom : this represents an increase of 2½d. per lb. Their prices for commercial die casting alloy and for 20 lb. ingots of primary magnesium of 99·9% minimum purity remain unchanged at 2s. and 2s. 3d. per lb., respectively.

Dowson and Mason's Golden Jubilee

AMONG the firms which, by their advertising, were associated with METALLURGIA in its first issues, and still are today—it is pleasing to note there are several—was one which this year is celebrating its golden jubilee. To mark the occasion, the firm—Dowson and Mason, Ltd., of Levenshulme, Manchester—has issued a leaflet about itself, which includes a section giving much useful information on how to get to the works by road or rail, parking facilities, telephone number, business hours, etc., together with the names of the executives and senior staff and their telephone extension numbers.

The central double-page spread features twenty-six illustrations of the varied products of the company, which range from industrial incinerators to meat pressing and clipping machines, from varnish boiling furnaces to galvanising baths, from storage tanks to dispensing columns for refuelling diesel locomotives, and from vacuum metallisers to heat treatment furnaces. It is as furnace makers that the company is most widely known to readers, and undoubtedly this has been its main interest for many years.

The Dowson and Mason Gas Plant Co., Ltd., was formed in 1910 by the amalgamation of the Dowson Economic Gas and Power Co., Ltd., of London, with the Mason Gas Plant Co., Ltd. of Manchester. The original Dowson Company was founded by J. Emerson Dowson, M.I.C.E., inventor of a simple producer gas generator for driving engines and for heating applications, both domestic and industrial. At the York meeting of the British Association in 1881, Mr. Dowson read a paper and demonstrated the producer with a 3 h.p. Otto gas engine. Later in the same year, he exhibited at a Smoke Abatement Exhibition, being awarded a gold medal and a prize of fifty guineas given by Sir William Siemens, F.R.S.

The Mason side of the story begins with the interest in mechanical baking ovens developed by Mr. Mason during residence in Holland, where he went at the age of 19 as representative of a Manchester engineering firm. On his return to England, Mr. Mason found his father-in-law, Mr. J. Rennison, of Belle Vue Zoological Gardens, experiencing difficulties in coping with the immense amount of baking required. Taking his ideas from the heating of gas retorts, Mr. Mason invented Jennison's patent smokeless decker oven and commenced manufacture in Longsight, Manchester, in 1870. The business was extended in 1897 by the introduction of the Duff gas producer, which was suitable for furnaces as well as bakers' ovens.

The increasing demand for gas producers led to the manufacture of furnaces, particularly of the Weardale design which was perfected after innumerable experiments. This was a big advance in furnace practice and proved suitable for the reheating of steel and similar operations. The design retained its popularity, and today many industrial furnaces are based upon variations of the same principle. The main feature was the introduction of a gas flame through a stratum of highly preheated air in the roof, so that the flame poured down and passed along the floor to the chimney ports. The furnace chamber was surrounded by an air space recovering heat which would otherwise have been wasted through the walls. The Mason business continued to develop, and in 1904, moved into larger premises in Levenshulme—the present headquarters of the company—where extensions were carried out in 1914, and again in 1959.

Interest in the supply of bulk petrol and oil storage equipment began in the early days of motor transport, when the first hand-operated petrol pumps were pioneered. A later development, the manufacture of electric petrol pumps, was only discontinued in 1939. The supply of petrol and oil storage tanks has increased tremendously, and today much of the fuel which keeps transport on the move all over Britain's roadways comes out of Dowson & Mason tanks. Moreover, railway diesel locomotives, road haulage and passenger transport vehicles and the nation's fishing fleets are refuelled through installations designed and built by Dowson & Mason.

Since 1900, the prime interest has been the construction of all types of industrial furnaces, and the company takes pride in the fact that many large steel vessels in the atomic power stations have been stress relieved in Dowson and Mason furnaces which include some of the largest in the world. In recent years, many large stress relieving furnaces have been built in this country, Denmark, Portugal, South Africa, Australia, New Zealand, Brazil and Mexico. A new extension of Dowson and Mason activities includes the design and construction of a comprehensive range of industrial incinerators devised to meet the requirements of the Clean Air Act, and a relatively recent association with Vacuum Metallurgical Developments, Ltd., has led to co-operation in the production of vacuum metallisers for the continuous coating of foil and paper.

Borated Graphite at Dounreay

WITH the starting-up recently of the fast breeder reactor at Dounreay in the North of Scotland, it has been disclosed that for the first time special borated graphite blocks were used by the United Kingdom Atomic Energy Authority in the assembly of the shield which surrounds the reactor vessel. The blocks were made and machined by The Morgan Crucible Co., Ltd., at their works at Norton, near Worcester. This factory is not engaged in the production of nuclear pure material and was therefore chosen as one suitable for handling large quantities of boron compounds.

The purpose of the borated graphite is to slow down fast neutrons and then absorb them in the shortest possible distance, thus providing a safety screen. Most of the borated graphite contained 0·3% boron, but some contained 5%—in both cases very uniformly distributed throughout the graphite. The blocks themselves were machined to 500 different patterns, some so intricate that wooden dummies had first to be made to ensure that it was practicable to machine them in graphite. As a final check, the layers of finished graphite blocks were assembled at Norton into their complicated form of eccentric circles.

THOMAS MARSHALL AND CO. (LOXLEY), LTD., have supplied the casting pit refractories to the new Durgapur steelworks and the first steel to be made will be teemed into ladles fitted with Marshall sleeves, stoppers and nozzles.

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NEWS AND ANNOUNCEMENTS

Corrosion Science Society

CORROSION topics are discussed by many institutes and societies in Britain, at meetings more often than not consisting of lectures and symposia on established matters. However, there exists no independent organisation bringing together scientists interested in the progress and practice of the science and technology of corrosion and its prevention for the discussion of current work.

A number of well-known workers in this field, believing that an independent body, consisting only of professional scientists and technologists working in the corrosion field, would be particularly well able to promote the advance of corrosion science, are founding the Corrosion Science Society with the following immediate aims :

(1) To promote the advance of corrosion science and its application to the solution of practical problems.

(2) To organise meetings—personal, local, national and international—of scientifically qualified persons interested in all fields of corrosion and corrosion-protection research and practice, for the discussion of current work.

(3) To co-operate with all other professional individuals, societies and institutes, British and foreign, with interests in the corrosion field.

The first meeting will be held on April 4th–5th, 1960, at Battersea College of Technology, London. Stress-corrosion cracking, the corrosion and protection of aluminium, cathodic protection, electrode processes and high-temperature corrosion and oxidation will be among subjects to be discussed on the basis of a series of talks by workers at present active in these fields, including C. Edeleanu, J. G. Hines, T. P. Hoar, J. E. O. Mayne, N. F. Mott, E. C. Potter and L. L. Shreir. All interested should write to either Dr. T. P. Hoar, Department of Metallurgy, Pembroke Street, Cambridge, or Dr. L. L. Shreir, Battersea College of Technology, London, S.W.11.

Electrolysis of Fused Salts Symposium

THE Electrometallurgy Centre of the Italian Metallurgy Association is organising a symposium on the electrolysis of fused salts and the production of special metals, which will be held in Milan from Thursday, May 5th to Saturday, May 7th, 1960. Several papers have already been announced, but others from overseas scientists would be welcomed. The title of the paper and a detailed summary should reach the Secretary of the Association by March 15th and the final text by April 15th. Further particulars may be obtained from the Secretary, Associazione Italiana di Metallurgia.

Institute for Powder Metallurgists

METALLURGISTS and others interested in powder metallurgy now have their own technical organization, called the American Powder Metallurgy Institute. A technology division of the Metal Powder Industries Federation, the Institute had previously been restricted to corporate membership, but growing interest in powder metallurgy and a corresponding increase in the number of individuals involved in the application of this technique caused the Federation's Board of Governors to open membership in the Institute to individuals. Membership is open to anyone having a bona-fide interest in powder metallurgy, who wishes to keep abreast of technical developments and business news about the industry.

Members will receive a monthly information bulletin containing the latest news of the industry plus abstracts of pertinent technical literature, and a quarterly publication devoted to current powder metallurgy applications. Members are also entitled to discounts on all publications of the Federation, including standards and meeting transactions. An annual directory of all Institute members will be published by the Institute and made available to the members.

Annual dues are $10 per year ; overseas members $15 per year. Charter membership in the American Powder Metallurgy Institute will be open until April 25th, 1960. After that date, a $5 initiation fee will be required. Advantages of belonging to the Institute are detailed in a brochure available from the American Powder Metallurgy Institute, 60 East 42nd Street, New York 17, N.Y.

Refresher Courses for Older Graduates

THE Department of Metallurgy, Battersea College of Technology, has organised a number of refresher courses for older graduates to be given at the college during the Easter and summer vacations in the current session. The courses will last 3–4 days and will be given by members of the college staff and visiting lecturers. The first courses planned will be as follows :—

"The Structure of Metals and Alloys." Easter Vacation, April 1960.
"Developments in Foundry Practice." Summer Vacation, July 1960.
"Austenite Transformation—The Present Position." Summer Vacation, September 1960.

The courses are intended for metallurgists who, having completed their academic studies some years ago, may now like to survey the present state of knowledge in fields additional to their own speciality.

World Powder Metallurgy Conference

THE 1960 International Powder Metallurgy Conference will be held at the Hotel Biltmore, New York City, on June 13th–15th. The first to be held in America, it is sponsored by the Metal Powder Industries Federation and the American Institute of Mining, Metallurgical and Petroleum Engineers, Powder Metallurgy Committee. Further information concerning the papers to be presented for discussion may be obtained from the Executive Secretary of the Metal Powder Industries Federation at 60 East 42nd Street, New York 17, N.Y.

Anglo-French Meeting

THE Non-Destructive Testing Group of the Institute of Physics will hold a meeting in London on May 2nd–4th, 1960 jointly with the Société Francaise de Métallurgie. The programme will have the general theme of the relationship between structure and physical properties of materials and will include recent advances in non-destructive testing techniques. Further details may be

obtained from The Secretary, The Institute of Physics, 47 Belgrave Square, London, S.W.1.

Selection of Alloys Course

A SHORT course of three lectures on the selection of alloys for engineering applications, from the viewpoints of the automobile, aircraft and marine engineer, will be held on successive Wednesday evenings at 7 p.m., at the Institute of Technology, Bradford, commencing on March 9th, 1960. Application forms giving further details may be obtained from the Registrar, The Institute of Technology, Bradford, Yorkshire.

London Metallurgists Meeting

THE London members of the Institution of Metallurgists are holding their Spring Meeting on Tuesday, March 22nd, 1960 at Battersea College of Technology, Battersea Park Road, S.W.11. Refreshments will be available from 6 until 7 p.m. and following this there will be a talk entitled "The Expert Witness" by Mr. E. A. G. Liddiard, Director of Research, Fulmer Research Institute.

British Instruments in Moscow

As a result of the report to the council by the three-man delegation of the Scientific Instrument Manufacturers' Association of Great Britain, which went to Moscow at the beginning of November, and the support from thirty members of S.I.M.A., an exhibition of British scientific instruments will be held in Moscow from June 16th to 26th, 1960. This exhibition will be the first to be put on in Russia by a British organisation of manufacturers in a specialised field. It is possible that some additional exhibitors will participate and further enquiries are still being received.

Research Scholarship

A RESEARCH scholarship in the use of light alloys in structural engineering is offered every third year by the Institution of Structural Engineers in collaboration with the Aluminium Development Association. The duration of the scholarship is two years and the value £600 per annum. The next award will be made this year to date from October 1st, 1960. Details and application forms are obtainable from the Secretary of the Institution of Structural Engineers. Completed application forms should reach the Secretary by March 31st, 1960.

I.C.I. Solvent Plant Extension

IMPERIAL CHEMICAL INDUSTRIES, LTD., is to build a major extension to its trichloroethylene and perchloroethylene plants at Castner-Kellner Works, Runcorn, at a cost of £1 million. Technical service and development work on the uses of these two solvents has been carried out by I.C.I. over many years, and this has led to a growing demand for both products, particularly in the engineering industry for metal-degreasing and also for dry-cleaning. The extension now planned will increase the company's combined capacity for these two solvents by 25%, and will enable I.C.I. to satisfy the demands of the home market for several years ahead and permit a further increase in its present considerable export trade. The extension will be based on a new manufacturing process which is expected to lead to lower production costs: it will be completed in 1961. Initial reductions of 30s. per ton in the price of trichloroethylene and £5 per ton in the price of perchloroethylene were introduced on January 1st, 1960.

Kelvin Hughes and Curtiss-Wright Agreement

AN agreement has been concluded between Kelvin and Hughes, Ltd. and the Curtiss-Wright Corporation of America for the exclusive right to manufacture and sell the non-destructive testing equipment of the other partner. This includes instruments for the inspection and measurement of materials, and equipment employing ultrasonic techniques in all industrial fields. The agreement covers certain defined territories. Kelvin Hughes will represent both interests in the U.K., the Commonwealth (except Canada) and Europe, and Curtiss-Wright in the U.S.A. and Northern America. Each party to the agreement will offer full sales and service facilities on the joint range of equipment.

Kelvin Hughes has developed a range of manual, semi-automatic and automatic ultrasonic test equipment. Curtiss-Wright also manufactures ultrasonic equipment but has, in addition, a range of industrial radiographical equipment using X-ray and gamma ray techniques. Immediate advantages of the new partnership will be that both organisations' equipment for non-destructive testing will be greatly increased. As, under the agreement, there will be no duplication of research and development, future progress in this field will be greatly speeded up.

Zinc Smelter Contract

As part of their £8m. expansion programme at Cockle Creek, near Newcastle, New South Wales, Consolidated Zinc have awarded a number of contracts to a total value of approximately £650,000 to Woodall-Duckham (Australasia) Pty., Ltd., a member of the Woodall-Duckham group of companies. The principal item embodies the construction of the blast furnace section and ancillary equipment for an Imperial Smelting type zinc smelter developed in the United Kingdom by Consolidated Zinc. This plant is the result of extensive Research and Large scale prototype plant tests at Avonmouth extending over many years, and the process is the first to utilise a blast furnace in zinc smelting: it can simultaneously produce a similar quantity of lead.

Abstract and Book Title Index Card Service

THE *Journal of The Iron and Steel Institute* contains each month about 750 abstracts of technical papers drawn from about one thousand journals and reports published in many languages. The importance of keeping abreast with the latest advances in science and technology is widely recognised but it is becoming increasingly hard to do so because of the growing volume of published information, its increasing complexity, and the mounting difficulty of organising its prompt reception and application.

In order to make abstracts available to users more

quickly and in a form more suitable for indexing than the printed abstracts section of the *Journal*, the Iron and Steel Institute is inaugurating an Abstract and Book Title Index Card Service, which will consist of pre-publication copies of all abstracts (together with titles of new books) due to be published in the *Journal of The Iron and Steel Institute*. It will begin with the abstracts due for publication in the January 1960 issue of the *Journal*, and will continue regularly in advance of the publication of the abstracts and book titles in the *Journal* (where they will continue to be printed).

The new service will be in the form of 5 x 3 in. cards (the international library size) sent to subscribers fortnightly, arranged and packed in alphabetical order of authors. Approximately 9,000 abstracts of technical articles and about 500 book titles will be covered each year. Single sets of cards will be useful, not only to companies that would like to have their abstracts arranged by authors, but also to those who wish to incorporate them into other single card systems. Additional sets of cards are offered at a reduced subscription for those who require them for systems of filing under more than one entry. Further particulars may be obtained from the Secretary, the Iron and Steel Institute, 4 Grosvenor Gardens, London, S.W.1.

Continuous Casting Agreement

CONTINUOUS CASTING CO., LTD., of Weybridge, Surrey, announces an agreement for technical collaboration with Low Moor Alloy Steelworks, Ltd., of Bradford. Low Moor Alloy Steelworks has, over a number of years, developed in its own works the continuous casting of stainless and alloy steel slabs, blooms and billets. Continuous Casting Co., Ltd., which is associated with Davy and United Engineering Co., Ltd., and Newton Chambers and Co., Ltd., is a licensee for the B.I.S.R.A. processes of continuous casting.

United Steel's New H.Q.

THE head office of The United Steel Cos., Ltd., has been transferred from its premises in Westbourne Road to new headquarters at The Mount, where there is office accommodation for a staff of approximately 150 people. Some will be housed in The Mount itself, a 126-year-old building which has undergone extensive internal reconstruction, while others will be accommodated in an entirely new three-storey block and interconnecting wing which have been built behind the main building. The company's new address is The United Steel Cos., Ltd., (G.P.O. Box 64), The Mount, Broomhill, Sheffield, 10. The telephone number remains unchanged at Sheffield 60081.

Films at B.A. Meeting

A SERIES of scientific film programmes will be screened during the Annual Meeting of the British Association for the Advancement of Science, to be held at Cardiff from August 31st to September 7th, 1960, including general programmes for both informed non-specialists and the general public, and specialist programmes including one devoted to world food and population problems, the subject of a major symposium at Cardiff.

The British Association would welcome suggestions for suitable films for inclusion in these programmes. Information about these films should include the title; whether silent or sound; whether black and white or coloured; running time in minutes; address of sponsor, producer, and distributor; a short synopsis of content and an indication of the type of audience for whom the film is intended. Details of films should be sent as soon as possible to the Visual Aids Officer, British Association for the Advancement of Science, 18 Adam Street, Adelphi, London, W.C.2.

Personal News

THE FAFNIR BEARING CO., LTD., of Wolverhampton, have announced the appointment of MR. G. MARCHANT as general manager of their Wolverhampton and Hednesford factories.

MR. W. H. WENTWORTH PING has been appointed general sales manager of Firth-Vickers Stainless Steels, Ltd. Mr. Ping was previously sales development manager. MR. D. G. GILL-DAVIES has been appointed export sales manager and MR. D. W. SMITH, assistant export sales manager.

MR. R. E. F. SYKES has been appointed general manager of Griffin and George (Laboratory Construction), Ltd., a subsidiary of the Griffin and George Group. Mr Sykes succeeds MR. A. E. LAMBERT, who has retired from the company, which manufactures laboratory furniture in wood and metal, and has works at Perry Barr, Birmingham and Mitcham.

MR. J. A. GODDARD, director and secretary of Fry's Diecastings, Ltd., has been elected chairman of the Zinc Alloy Die Casters Association for 1960. He succeeds MR. K. J. WHITEHEAD, joint managing director of Wolverhampton Die Casting Co., Ltd.

UNION CARBIDE, LTD. have announced the appointment of MR. H. CAWLEY to the position of Sheffield area sales manager; his office is located at Grange Mill Lane, Wincobank, Sheffield.

BRIGADIER H. P. CROSLAND, C.B., C.B.E., M.C., T.D., D.L., chairman and managing director of Metal Traders, Ltd., has been elected chairman of the Zinc Development Association for 1960. The former chairman, MR. R. T. DE POIX, O.B.E., will continue as a member of the council of the Association.

PYE PROCESS HEATING have announced the appointment of MR. R. P. HEATLEY, as sales manager. Previous to his new appointment, Mr. Heatley was for many years a senior member of the Woden Transformer Company.

ASSOCIATED ELECTRICAL INDUSTRIES, LTD., have appointed SIR ARTHUR ELTON, BT., to be the controller of their central information department, as from March 1st. Sir Arthur has, for the last three years, been in charge of films and television in the public relations division of the Shell International Petroleum Company. MR. S. C. LESLIE, who was appointed a year ago as A.E.I.'s consultant on information policy has been acting for the past six months as the head of the central information department during the process of its establishment. After Sir Arthur Elton's arrival he will be free to resume his consultancy duties in the wider field of both external and internal policy on information.

CONSEQUENT upon his appointment to the executive board of The Incandescent Heat Co., Ltd., MR. P. M. WILLIAMS has now relinquished his post as manager of

the foundry plant division of the company, where he is succeeded by MR. J. S. PERKS, previously assistant manager. The new assistant manager is MR. M. JURKOWSKI.

DR. M. COOK who has been chairman of I.C.I. Metals Division for the past two years, retired from the company's service on December 31st, 1959. He is succeeded by MR. M. CLAPHAM, a joint managing director. Dr. Cook joined the research department of Kynoch, Ltd., in 1926. He was appointed research manager of the metals group of I.C.I. in 1938, and director in charge of research and development, Metals Division, in 1942. He became joint managing director in 1951 and chairman in 1957. Until his retirement he was a director of Yorkshire Imperial Metals, Ltd. An extremely well known figure in the world of metals, Dr. Cook is a former president of the Institute of Metals, a past president of the Institution of Metallurgists (of which he is a founder fellow), chairman of the British Non-Ferrous Metals Research Association, a vice-president of the British Non-Ferrous Metals Federation, a member of the board of the British Nuclear Energy Conference, and a member of the general board and executive committee of the National Physical Laboratory. In 1956 he was awarded the Platinum Medal of the Institute of Metals in recognition of his contributions to the science of metallurgy, to the non-ferrous metal industry and to the welfare of the metallurgical profession.

A.E.I. (Rugby), Ltd., have announced the appointment of MR. D. EDMUNDSON as general manager, Rugby works. This will enable MR. H. E. COX, who has been general manager since 1957, to devote his time to the duties of deputy director of manufacture. Mr. Edmundson served an engineering apprenticeship with B.T.H., and in 1946, he was appointed test engineer, Rugby works, eventually becoming superintendent, test department. In 1957, Mr. Edmundson was appointed assistant manager–manufacturing, being promoted manager–manufacturing at the beginning of 1959.

The British Iron and Steel Research Association announces that MR. S. S. CARLISLE, head of the physics department, has been appointed an assistant director. He will be especially concerned with the co-ordination of the Association's work on automation and information handling, which is now a vital part of the research programme. Mr. Carlisle joined B.I.S.R.A. in 1946, and in 1947 was appointed head of the instruments section of the physics department. In 1954 he was made head of the South Wales laboratories, where the association's work on steel coatings research is carried on, and he returned to London in 1958 as head of the physics department.

MR. A. W. GRAHAM has taken over the appointment of manager, northern area, of Electro-Chemical Engineering Co., Ltd., from MR. H. MAXWELL. His address is Chaddock Industrial Estate, Astley, Nr. Manchester, (Tel : Atherton 1364). Mr. Maxwell has been appointed sales manager and will be operating from the company's head office at Sheerwater, Woking, Surrey.

MR. J. P. JESSOP, at present manager of The United Steel Cos. (Pakistan), Ltd., has been appointed managing director of that company in succession to MR. L. L. BOYD, who is returning to this country to become deputy commercial manager of Steel, Peech and Tozer. MR. R. M. MARSHALL, who has spent several years with The United Steel Cos. (India) Pte., Ltd., and who is at present completing a two-year course at the Harvard University Graduate School of Business Administration, will succeed Mr. Boyd as managing director of the Indian company. Mr Marshall will not be available to take up this appointment until September/October 1960. In the interim period from mid-February, MR. S. B. WAGH, director and secretary of the Indian company, will be responsible for it. MR. S. KUMAR will be in charge of sales in Bombay and MR. G. HILL in Calcutta, both responsible to Mr Wagh.

DR. J. G. PEARCE, C.B.E., has been appointed as a consultant to the Alloys Division of Union Carbide Ltd., and will work in collaboration with Dr. A. M. Sage and his team in their development programmes. MR. G. V. JONES, formerly of A.P.V.–Paramount Co., Ltd., has joined the development department of the Alloys Division, where he will mainly be concerned with the developments associated with the cast iron industry.

MR. T. L. MARTIN, director and general manager of West Instrument, Ltd., manufacturers of temperature control instruments and ancillaries, left on January 14th for the United States, where he will spend some weeks studying the latest American advances in pyrometer techniques.

MR. C. PULLAN, sales director of Armstrong Whitworth (Metal Industries) and Jarrow Metal Industries has retired from executive duties after thirty years' association with these companies. He remains on the board of directors, however, where his experience in a consultative capacity will be of great value.

MR. J. E. C. BAILEY, C.B.E., chairman and managing director of Baird and Tatlock (London), Ltd., and Hopkin and Williams, Ltd., left by air on January 30th to visit the companies' branches, agents, representatives and customers throughout East, Central and South Africa.

AFTER an association of nearly fifty years with John Summers and Sons, Ltd., MR. M. J. B. WHITBY has retired from his position as London manager. MR. F. H. SMITH, formerly market research and development manager, has succeeded Mr. Whitby as London manager.

MR. G. A. D. SMITH has been appointed commercial managing director of I.C.I. Metals Division. Mr. Smith, who is 47, joined the secretary's department of the division in 1936, and on demobilisation in 1947, he was appointed personal assistant to the commercial managing director of Metals Division. Mr. Smith was appointed to the Board of I.C.I. Metals Division in 1951 and has since served as sales director and commercial director.

MR. R. T. W. ANDERSON has been appointed district manager at the Birmingham works of British Electrical Repairs, Ltd. He succeeds Mr. J. Ashmore, who is retiring after twenty-six years as district manager at Birmingham.

Wakefield-Dick Industrial Oils, Ltd., have appointed MR. J. W. DAVIES as their representative for the Sheffield area, in succession to MR. A. S. WATSON, who retires after thirty-five years in a similar capacity.

DUE to increased activities in other directions, MR. W. CORFIELD has relinquished his Lancashire and Cheshire agency with Radiovisor Parent, Ltd. The company is in the process of opening its own Northern office under the direction of MR. A. C. STEWART, who will be assisted by MR. D. A. DAWSON.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

Shell Moulding Equipment

THE Efco Foundry Division has introduced two new items of shell moulding equipment—the Reynolds shell moulding machine and the Reynolds shell mould closing machine. The former is a manually-operated unit and has two investment boxes and two heating units for making the two halves of a mould. The boxes are positioned at each end of a steel framework which has at the centre an idling position for the heaters. The framework provides a horizontal track on which the pattern plates, mounted on rollers, can be moved quickly from the heating positions to their investment boxes. The heating units, which are fitted with electric elements providing rapid heating by radiation, are suspended from a rear framework and are easily moved in any direction.

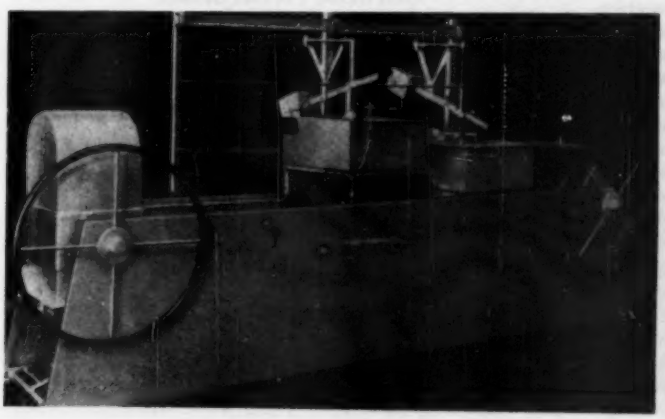
When a pattern plate has been heated to the required temperature, the heating unit is removed to the idling position and the plate is moved to its investment box, where it is tilted at the right angle for securing it to the open end of the box with quick acting clamps. The investment boxes are up-ended with large diameter hand wheels to provide the dumping action which compresses the sand to the shape of the pattern. After 8–15 seconds, depending upon the thickness of shell required, the box can be moved back to its original position and the invested pattern plate returned to the track, where it is again covered with a heating unit to complete the curing of the resin-impregnated sand. The shell is finally stripped from the pattern by spring-loaded plungers brought into action with a foot lever. This machine will make shells up to 18 in. by 14 in., and one operator can produce 25 complete moulds an hour.

The shell mould closing machine is designed for joining with a resin adhesive the two halves of a mould received while still hot from the moulding machine. The shells are placed in one of two loading stations, where they are supported on spring-loaded plungers, liquid or powdered thermo-setting adhesive having been applied to the lower half mould. The moulds are accurately positioned against stops. The loaded station is moved into the closing press where a top plate, equipped with a corresponding set of plungers, is raised and lowered by a pneumatic cylinder. The press is closed and the adhesive sets in a few seconds. The loading stations are used alternately; as one is moved into the press it pushes the other to an unloading position. The machine is fitted with two side tables where the hot shells from the moulding machine can be placed, face down, until they have passed the thermo-plastic stage and can then be supported on the plungers. The machine will accommodate half moulds up to 6 in. deep, and any reasonable number of plungers may be used. Output of the machine depends upon the setting time of the adhesive, which can be as short as 30 seconds, when a single operator can easily close a hundred moulds an hour.

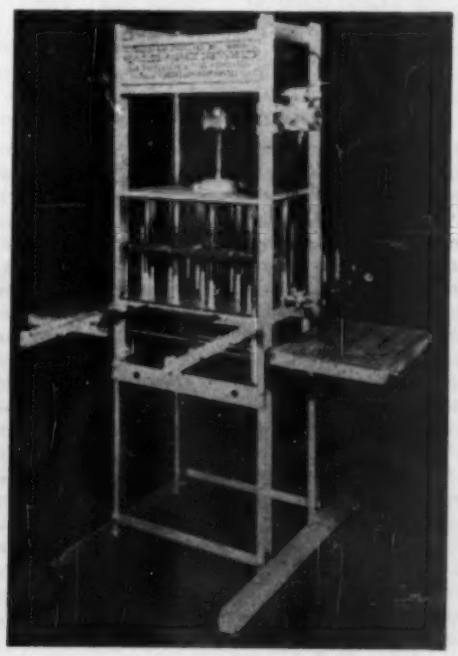
Electric Furnace Co., Ltd., Foundry Division, Queen's Road, Weybridge, Surrey.

Electric Valve Actuator

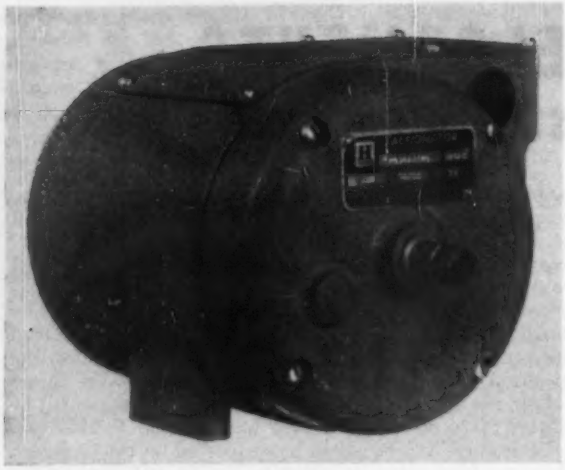
A HEAVY duty electric motor for operating butterfly and rotary stem valves, dampers and louvres, or vertical acting slip stem valves, is now available from Honeywell Controls, Ltd. Known as the Actionator, it consists of a reversing capacitor type motor with a gear train to give the required timing. Various speeds are available ranging from 9·0 sec. to 144 sec. for 180° rotation or full stroke



Reynolds shell moulding machine



Reynolds shell mould closing machine



Honeywell Actionator motor.

operation. Torque output is high—up to 200 lb. in.—and there is an internal brake to hold the load in any position without " hunting " or " coasting " when the motor is de-energised.

Models of the Actionator are available for two-position, floating or proportional control action. Cam-operated micro switches control the extent of motor travel in either direction, and up to four auxiliary switches of the same kind can be incorporated. A re-transmitting slidewire can be substituted in the proportional control model.

The Actionator is ruggedly constructed—all components are housed in a die-cast aluminium housing—and it will work continuously without loss of efficiency in ambient temperatures as low as 25° F. and as high as 150° F.; it requires no maintenance.

Honeywell Controls, Ltd., Ruislip Road East, Greenford, Middlesex.

Automatic Dust Filter

In collaboration with the German company of Otto Hubbe, Keith Blackman Ltd., are now manufacturing under an exclusive licence arrangement the well-established Fischer automatic dust filter. This filter is available in two basic types, one of square section containing 24 rectangular filter pockets and the other of circular section containing 27 circular filter sleeves. The dust-laden air passes first into the collection hopper, where the heavy particles are settled out, and then through the fabric filter pockets in the filter chamber, where the remaining dust is trapped. The clean air passes out into the main extraction duct leading to the fan, the filter chamber always operating under suction.

Two or more filters are installed adjacent to one another, the number depending on the volume of air and dust passing into the filters. At predetermined intervals, which depend on the conditions under which the plant is operating, a motor-operated damper in one of the filters causes the dust laden air to by-pass the filter, which then undergoes its cleaning cycle. The same motor simultaneously opens another damper and air is drawn through the purging air inlet into the filter chamber (which is under suction), passes through the pockets in the reverse direction (from outside to inside), carrying the collected dust into the main dust collection hopper, where most is deposited. The purging air then passes into the inlet duct to be mixed with the dust-laden air which is being directed to the adjacent filters, which are meanwhile in normal operation.

While the reverse process is taking place a high frequency vibrating mechanism agitates the pockets in a horizontal plane to dislodge the dust particles clinging to the filter bags, thus avoiding the stresses often caused by the " concertina " effect of vertical shaking gear. Thus the Tornado-Fischer filter sleeves or pockets have a much longer life, reducing maintenance and replacement costs to a minimum. The shaking mechanism is completely self-contained in dust-tight cast iron enclosures, and there is thus no fear of any moving part being affected by dusty atmospheric conditions.

Keith Blackman, Ltd., Mill Mead Road, London, N.17.

High Temperature Ammonia Dissociators

For some years the use of 75% hydrogen/25% nitrogen mixtures (derived from cracked ammonia) has grown steadily. More recently the high temperature cracker has increased in popularity as it obviates the necessity of water scrubbing to remove residual ammonia. In consequence, the benefits of the extremely low oxygen and water vapour concentrations obtained in ammonia crackers are maintained, without the high capital cost of additional drying and other purifying equipment. Using a specially developed catalyst with exceptionally long life and high activity, high temperature ammonia crackers are now being produced by the Gas Atmospheres Division of the Incandescent Heat Co., Ltd., to the design of the Drever Co., Bethayres, U.S.A. These plants have outputs from 150 to 5,000 s.c.f.h. and are produced in ten standard sizes.

High temperature cracked ammonia is used in the heat treatment of metals, sintering, welding, controlled nitriding, degassing of metal parts, and in metal cleaning by the sodium hydride process. Copies of articles giving information on metallurgical and other uses of cracked ammonia, may be obtained from the makers.

Gas Atmospheres Division, The Incandescent Heat Co., Ltd., Smethwick, Birmingham.

Chrome Neutraliser

The use of Canning's Chrome Neutraliser affords a simple method of neutralising and chemically reducing the chrome solution carried over on plated components as they are transferred from the drag-out tank after chromium plating. For this purpose it has an advantage over sodium bisulphite in that it may be used in a plain steel tank. In use, it not only neutralises any free acid remaining upon the surface of the chromium plated articles, but also reduces the residual chromate to the green trivalent state. The usual process sequence after chromium plating is: drag-out, neutralise, cold swill, hot swill and dry. The Chrome Neutraliser may also be used, very effectively, on automatic nickel and chromium plating plant for the removal of chromic acid entrapped in jigs or absorbed by jig coatings, thus preventing chrome contamination of the cleaning line.

W. Canning and Co., Ltd., Great Hampton Street, Birmingham, 18.

CURRENT LITERATURE

Book Notices

PRECIPITATION PROCESSES IN STEELS

xiv + 322 pp., 77 line drawings, 126 photographs, bound in cloth with board covers. Special Report No. 64 of the Iron and Steel Institute, 4 Grosvenor Gardens, London, S.W.1. 84s. (members 63s.) + 1s. postage.

In recent years the large amount of work carried out to investigate precipitation processes in alloy steels has emphasised the great practical importance of this subject. The Department of Metallurgy in the University of Sheffield, led by Professor A. G. Quarrell, decided in the summer of 1957 that the time was ripe for a more detailed discussion of precipitation processes, and that Sheffield would be an appropriate place for such a conference to be held. Sixteen papers were invited from outstanding workers in this field in Belgium, France, Germany, Sweden, the U.K. and the U.S.A., and these were presented and discussed at a three-day meeting held in the University of Sheffield in July, 1958. The attendance at the meeting was about 150, ten countries being represented.

The papers were divided into four groups for discussion, the groups being as follows: precipitation in ferritic steels, precipitation in austenitic steels, intergranular fracture in steels, and precipitation during creep. There was a lively and valuable discussion on the papers in each group, and much new information was presented. Much of the literature in this field is scattered through a wide range of periodicals and many languages, and it was therefore considered that it would be of the utmost value to those engaged in research on precipitation processes for all the papers at the Sheffield conference to be published in a single volume. The organisers of the conference offered the proceedings to the Iron and Steel Institute for publication in the Special Report Series, and the present volume is the outcome.

BRITISH AND FOREIGN SPECIFICATIONS FOR STEEL CASTINGS—PART 1

10 × 8 in., xiv + 48 pp., paper covers. The British Steel Castings Research Association, East Bank Road, Sheffield, 2. 40s. postage paid, $7·50 in U.S.A. and Canada.

A type of enquiry frequently received by the British Steel Castings Research Association in recent years has been: "What sort of steel is denoted by the following letters and numerals?"—"If a standard specification is involved, what body issues it?"—"What is the nearest British Standard?" The volume of these enquiries has grown to such an extent—and the possible advent of a European free-trade area and the general increase in international trade is likely to swell it still further—that the Association has compiled the present guide-book, which presents in summary form the main requirements for steel castings of the national standardising organisations in the various countries: private and semi-confidential specifications are not included. Part 1 covers in this way Austria, Belgium, France, Germany (both East and West), Sweden, Switzerland, the U.K. and the U.S.A. Additionally, lists of standards current in Czechoslovakia, Holland and Italy are provided. Part 2, to be issued later, will include the Commonwealth countries and additional foreign countries.

Produced primarily for steelfounders in the U.K. and the Commonwealth, this "guide" will doubtless be of value to designers and purchasers of steel castings in many countries, and indeed to a large number of metallurgical and engineering institutions, colleges, technical reference libraries and information bureaux.

Trade Publications

The main article in the January issue of *Platinum Metals Review* surveys the most important applications of the platinum metals in the glass industry and outlines some newer developments. The article emphasises that the use of platinum equipment in the melting and working of glass has always resulted in an economy in manufacture, due entirely to the production either of a purer glass or of a glass free from defects of various kinds. Other articles in this issue deal with the palladium plating of printed circuits; the constitution and properties of the iridium-platinum alloys; and the behaviour of platinum-faced titanium and tantalum electrodes for cathodic protection in fresh waters. The usual compilation of abstracts of current literature on the platinum metals and their alloys is also included. Copies may be obtained on request from Johnson, Matthey and Co., Ltd., 78 Hatton Garden, London, E.C.1.

To salute the achievements of the dairy industry's thirty years of experience in the use of stainless steel, the Stainless Steel Manufacturers' Association have published an attractive 24-page illustrated brochure. As well as describing the application of stainless steel to modern dairy equipment, "Stainless Steel in the Dairy Industry" contains some useful technical notes, design criteria and fabrication details. Copies of the brochure can be obtained on application to the Association at 4 Melbourne Avenue, Sheffield, 10, or from any stainless steel manufacturer.

We have recently received from the Resistance Furnace Division of Metalectric Furnaces, Ltd., three new leaflets. The first, No. M.6A, is concerned with continuous bright annealing and includes a description of the various types of unit available for this operation, and of plants for the production of reducing or neutral atmospheres for use in them. No. M.9B deals with the Metalectric standard range of M.H.T. furnaces, which use silicon carbide type elements to obtain operating temperatures up to 1,400° C., and which are available as standard units in sizes ranging from 15 to 60 kW. The third leaflet, No. M.18A, details the standard Metalectric H.T.S. type high temperature electrode salt baths for treatments in the high temperature range up to 1,350° C., particularly for high speed steels.

The last of the units comprising the company's development programme, the combined rod, bar and narrow strip mill at Lackenby, is featured in *Dorman Long Illustrated* 1959. Modern efficient production units are, however, only fully utilised if backed up by an efficient sales organisation, and reference is made to this, too. Other items are concerned with the constructional engineering

activities of the company and its associates ; the work of the chemical group, which handles the by-products of the coke-oven plants ; the extension to the sinter plant at Cleveland ; and developments at the wire works, where the 8,000 tons of high tensile wire for the main cables of the Forth road bridge will be manufactured.

ROLL turning and profiling lathes of entirely new design, having a 17 in. height of centres and varying in length, are described in the November-December, 1959, issue of *Craven Machine Tool Gazette*. A further feature deals with the Craven wheel lathes which are now available with profile copying equipment.

WRITTEN primarily as a brief introduction to a tour of the Darnall Works in Sheffield of Davy-United, a new 44-page booklet also provides a guide to the organisation of the group and the type of plant produced, reference being made to a number of notable contracts handled in recent years for the world's metal industries. A fairly complete account of the resources of the works is presented and the illustrations show clearly the extensive workshops and the outsize machines necessary for manufacturing modern heavy duty rolling mills, hydraulic presses, etc. The use of more than 10 tons of timber in the pattern for the crosshead of a large forging press gives some indication of the scope of operations.

THE fact that the better class badges and brocade—whether naval, military or blazer—are made from strands of wire which are of silver or gold-plated silver is disclosed in a note on the production and heat treatment of such wire in the second (January) issue of *Efco Journal*. Also appearing in this issue are the concluding part of an account of a lecture, presented in London and the provinces by Mr. J. McMullen, on recent heat treatment developments ; a description of an oil heated core drying oven installation in Switzerland ; and instructions on the operation of an endothermic generator to achieve the best possible results.

FOR the first time, I.C.I. Metals Division has issued a comprehensive publication covering all its main copper and brass sheet and strip production. The booklet, which bears the title : " I.C.I. Sheet and Strip—Copper and Copper Alloys "—opens with a description of the production plant, followed by a discussion of product quality. The main section of the book is devoted to data on those metals and alloys which are in most general use, or which are representative of their particular group. Included in this section are copper, brasses, copper-nickel alloys, bronzes and special alloys.

TWO new leaflets received from Kodak, Ltd., concern the DN-20 developer and the RP.12 and RP.35 recording papers. DN-20 is a tank developer with one basic solution for developer and replenisher, and the new papers have been developed for speedier recording. RP.12 is designed for use in recording equipment incorporating a light source of sufficient intensity to give a visible " print-out " image in a few seconds without processing. RP.35 combines an existing high speed emulsion with a special thin base, which enables more paper to be loaded into the recording equipment.

" A STUDY OF TEMPERATURE UNIFORMITY IN HEAT TREATING " is the subject of an eight page reprint available from Ipsen Industries, Inc., manufacturers of heat treating units and related equipment. The author, H. N. Ipsen, discusses temperature uniformity and furnace design, and describes a series of tests conducted to measure temperature variations within the heating zone when a charge is placed in the furnace and brought up to heat. The series of tests was run at 1,550° F., (850° C.) and repeated at 1,850° F. (1,000° C.). The reprint includes graphs showing test results under three conditions : with baffle and no fan ; without a baffle and with a fan ; and no with baffle and fan. A discussion of controlled forced convection heating and temperature uniformity concludes the article. Copies are available on request to Ipsen Industries, Inc., 715 South Main Street, Rockford, Illinois.

EDWARDS HIGH VACUUM, LTD., have just published a 28-page catalogue devoted entirely to plant suitable for technical applications in lens blooming, front surface mirrors, interference filters, cathode ray tubes, quartz crystals, selenium rectifiers and roll coating of tissue for paper capacitors. The booklet describes the 12E series of coating units, with the new 12E7 for multi-layer work and the 12E6 shadow casting unit ; the 18E4, which has a long history of successful application in the optical industry ; the 19VE5, specially designed to meet the need for single and multi-layer thin films on large surface areas ; and the various functions of the 24E for mirror coating, selenium plating and cadmium plating. Finally a number of non-standard installations is illustrated.

Inco-Mond Magazine No. 12 features important applications of the austenitic nickel-containing stainless steels in many and varied industrial and domestic fields. Architectural metal work and catering and food processing plant are made from nickel-containing stainless steels because of their fabricating and corrosion resisting qualities, and articles in this issue illustrate typical applications. An unusual use of stainless steel is in the equestrian world where the modern trend is to use 18–8 for harness, bridles, bits and spurs. *Inco-Mond Magazine* is obtainable free on request from The Mond Nickel Co., Ltd., Publicity Department.

The Wild-Barfield Heat Treatment Journal for December features a description of the Electrolytic Copper Refinery plant at Garfield, Utah, U.S.A., where three 15 ft. diameter Lectromelt electric arc furnaces are used for melting cathodes for casting into refined copper shapes, and for melting anode scrap for the production of further anodes. Other articles deal with a G.W.B. pit furnace for heat treating jet engine parts, and the Wild-Barfield N.R.C. 600 lb. vacuum induction furnace installation at Jessop-Saville, Ltd.

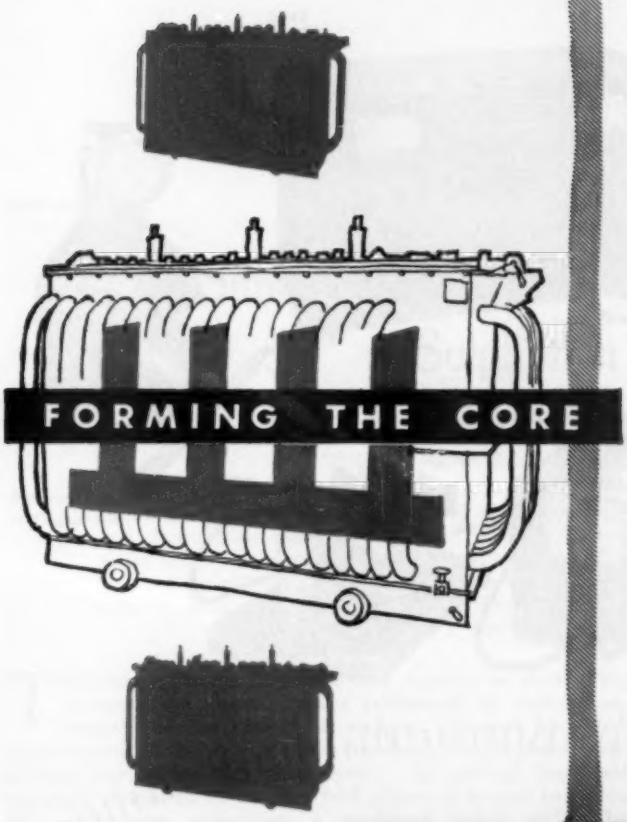
Books Received

" Nuclear Reactor Materials." By B. R. T. Frost and M. B. Waldron. 79 pp. inc. index. London, 1959. Temple Press, Ltd. 12s. 6d. net.

" Foundry Engineering." By H. F. Taylor, M. C. Flemings and J. Wulff. 407 pp. inc. index and numerous illustrations. New York and London, 1959. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 78s. net.

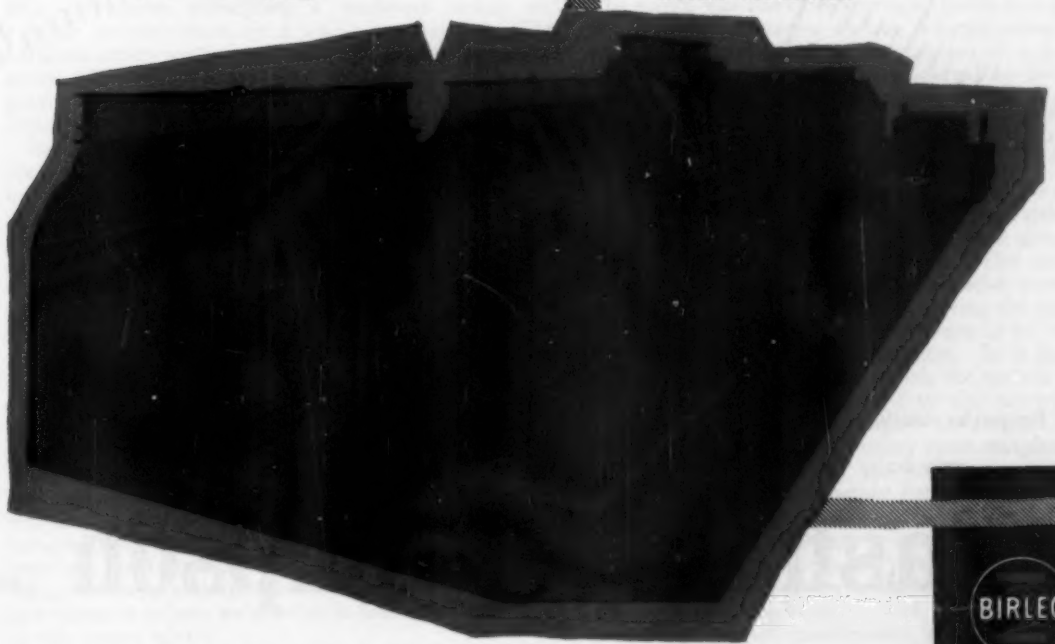
" Analysis of Deformation." Vol. IV.—" Waves and Vibrations." By K. Swainger. 370 pp. inc. author and subject indexes. London, 1959. Chapman & Hall, Ltd. 75s. net.

" Extractive Metallurgy." By J. Newton. 532 pp. inc. index. New York and London, 1959. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 78s. net.



These 180 kW Birlec bell furnaces at the works of Joseph Sankey & Sons Manor Works Ltd., Wolverhampton, have been installed for the high temperature annealing of hot-rolled silicon steel sheet for transformer cores. Two more Birlec installations, totalling a further ten bell furnaces, form a substantial part of Sankey's annealing capacity. Some 450 tons of transformer sheet, with a finished value exceeding £36,000, are treated each week in Birlec Furnaces.

* *The cost of a furnace is not necessarily its purchase price. Even a brief interruption in production may cause severe losses in output and serious inconvenience. The purchaser of a Birlec furnace can be confident that the equipment will not only meet his specification, but will give uninterrupted trouble-free service.*



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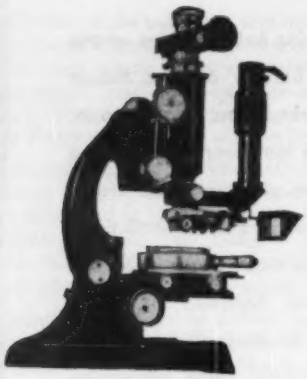
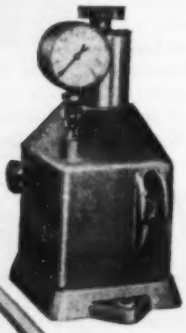


Swirl
Electrolytic Polisher



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LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS
JANUARY, 1960. Vol. LXI, No. 363

The Simultaneous Determination of Carbon and Sulphur in Steel

By C. E. A. Shanahan and R. H. Jenkins

R.T.B. Central Research Laboratories, Aylesbury.

Details are presented of the influence of oxygen flow rate on the rate of sulphur evolution from 1 g. of steel chips during combustion at 1,280° C. The influence of a 2 minute preheat is studied, and it is shown how the data may be used to develop a method for combined sulphur and carbon determinations in which the carbon is assessed with a Ströhlein unit. As an example of using the data, a suggested technique is described and its reliability illustrated by combined carbon and sulphur determinations on several standard steels.

THE determination of carbon and sulphur in steel is nowadays almost always performed by combustion of the sample in oxygen, followed by measurement of the amount of carbon dioxide or sulphur dioxide leaving the combustion tube. In spite of the apparent similarity of the two techniques, it is rare to find laboratories attempting a combined carbon and sulphur determination on a single combustion. This situation arises partly because of the greater versatility associated with two separate combustion units, and partly because of the different combustion conditions required for the two elements.

Several workers have published procedures for the combined determination of carbon and sulphur. As far back as 1924 Holthaus[1] described a technique in which the sample was burnt in oxygen at 1,200° C. and the sulphurous gases absorbed in hydrogen peroxide solution and estimated by titration with caustic soda. The carbon dioxide was absorbed in caustic alkali from the oxygen leaving the sulphur absorption unit, and determined by titrating the excess alkali with hydrochloric acid. More recently Holler, Klinkenberg, Friedman and Aites[2] have used a method in which the sulphurous gases are absorbed in a starch solution and titrated iodometrically; the carbon dioxide is estimated gravimetrically by absorption in Ascarite after drying the water-saturated gases with concentrated sulphuric acid and magnesium perchlorate. In 1955 Bjerkerud[3] described a technique adopted for routine use by the Surahammar Laboratories, whereby the sulphurous gases are determined iodometrically after absorption in starch solution, and the carbon dioxide determined by absorption in caustic soda solution followed by titration of the excess alkali.

The present work arose from the desirability of installing a rapid method for the combined determination of carbon and sulphur in steel that would be suitable for use in a steelworks melting shop stage laboratory. Methods relying on a gravimetric carbon determination such as that of Holler *et al*[2] were considered unsuitable, since they involved the thorough drying of water-saturated gas and, consequently, the frequent renewal of the desiccant. Moreover, the danger always exists, in laboratories under heavy pressure of work, that the desiccant may be retained beyond its useful life and thereby give rise to errors in the carbon determination. The choice was therefore narrowed down to a procedure involving a volumetric carbon determination, such as that of Bjerkerud,[3] or the installation of a gasometric determination (Ströhlein), as suggested by Seuthe.[4] It was decided to adopt the latter, since the technique would be ultimately used in a laboratory where the operators were already skilled in the operation of the Ströhlein carbon apparatus.

In order to develop a rapid technique for the combined determination of carbon and sulphur, it is important to assess the optimum oxygen flow rate for a given type of sample and combustion conditions. The carbon and sulphur should be evolved in the shortest possible time and, if possible, the total oxygen leaving the combustion tube should be small enough in volume to be completely contained within the Ströhlein unit. It is possible, of course, to use conditions in which the carbon evolution is complete, and then by-pass to the atmosphere the extra oxygen required to complete the sulphur evolution, but this procedure is obviously more complicated than a method in which all the oxygen passes to the Ströhlein unit. Unfortunately, little can be deduced from the literature on oxygen flow rates which could help in the present investigation, and in the few cases where some systematic research has been conducted concerning oxygen, the combustion conditions employed differed markedly from those adopted by the authors. The first part of the present investigation has, therefore, involved an examination of the rate at which sulphur is evolved from steel under constant combustion conditions but variable oxygen flow rates. The second part is concerned with the formulation and testing of a combined carbon and sulphur determination procedure using the oxygen flow data.

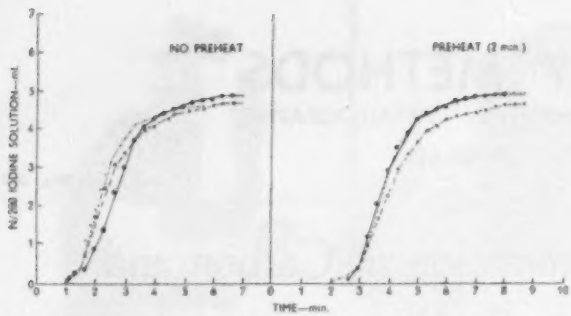

Fig. 1.—Sulphur evolution v. combustion time (exit gas flow rate 100 ml./min.).

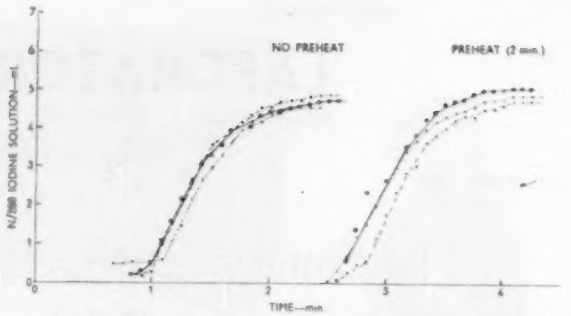

Fig. 2.—Sulphur evolution v. combustion time (exit gas flow rate 200 ml./min.).

Experimental Method

Relationship between Rate of Sulphur Evolution and Oxygen Flow Rate (No Preheat).

The apparatus consisted of a $\frac{3}{8}$ in. diameter and 2 ft·6 in. long aluminous porcelain combustion tube heated to 1,280° C. by means of a Silit rod furnace. Oxygen, purified by passing through anhydrone and soda asbestos, was led into the combustion tube which contained 1 g. of the sample, and the outgoing gases were passed through a capillary-type flowmeter and then into 50 ml. of water containing 1 ml. of 1% starch solution, within a 100 ml. measuring cylinder. A 10 ml. burette containing N/200 standard iodine solution was positioned above the cylinder, so that the sulphurous gases absorbed in the measuring cylinder could be titrated during the course of combustion. The procedure for determining the effect of oxygen flow rate was as follows : 1 g. of steel chips of a standard steel (B.C.S. 218/1 : sulphur content 0·045%) was weighed into a previously ignited aluminous porcelain boat, placed into the hot zone of the combustion tube and the oxygen flow adjusted immediately to the flow rate under study. It should be emphasized that the flow meter was situated at the exit end of the combustion tube, and therefore only measured the flow of excess oxygen (together with the carbon and sulphur oxides) ; thus, at the commencement of combustion, the measured flow rate was considerably below that of the oxygen entering the combustion tube. The standard iodine solution was continuously added during the combustion to maintain the blue endpoint, and burette readings were recorded at 5 and 10 second intervals. This procedure was repeated three times for each of four oxygen flow rates, viz : 100, 200, 300 and 400 ml./min. The data are plotted in Figs. 1–4.

Effect of Preheat

It is standard practice in some laboratories to adopt a " preheat time " for the sample before commencing the oxygen flow, and it was therefore considered advisable to examine its effect on the rate of sulphur evolution at various oxygen flow rates. The above work was therefore repeated using a 2 minute preheat time. This involved placing the boat containing the sample into the hot zone of the furnace and admitting only sufficient oxygen for combustion and for the maintenance of the gas pressure within the combustion tube, thereby avoiding " suck-backs ". After this period the oxygen supply was adjusted to produce the desired exit gas flow rate and the rate of sulphur evolution determined as above. The data are plotted in Figs. 1–4.

Combined Sulphur and Carbon Determinations

The apparatus shown in Fig. 5 was used for the simultaneous determination of carbon and sulphur in several steel standards making use of the data given above. Two modifications were made to the combustion train already described ; the open 100 ml. measuring cylinder was replaced by a boiling tube carrying a rubber bung and gas entrance and exit tubes and a " Ströhlein type " carbon dioxide absorption unit attached to the end of the train. Unfortunately, a commercial " Ströhlein " unit was not available, and a similar apparatus had to be fabricated in the laboratory.

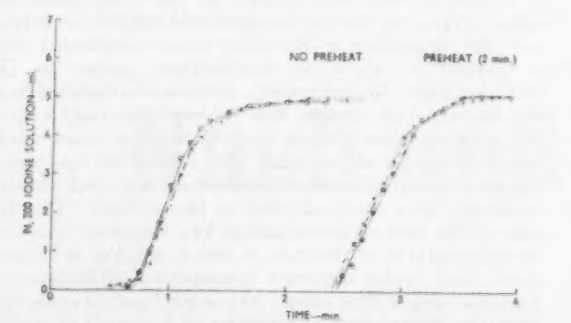

Fig. 3.—Sulphur evolution v. combustion time (exit gas flow rate 300 ml./min.).

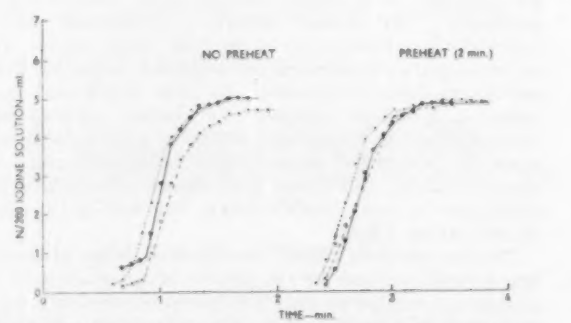

Fig. 4.—Sulphur evolution v. combustion time (exit gas flow rate 400 ml./min.).

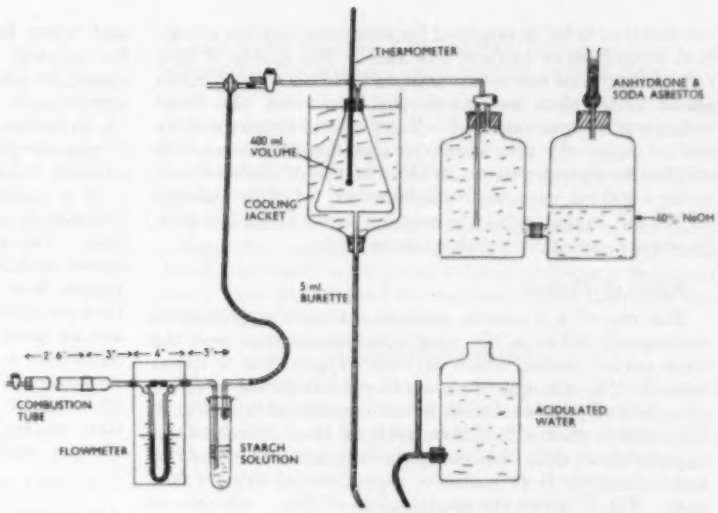

Fig.5.—Apparatus for simultaneous carbon and sulphur determination.

The burette was capable of retaining approximately 400 ml. of gas.

The procedure adopted was as follows. Approximately 1 g. of the steel chips was accurately weighed and transferred to an aluminous porcelain boat previously ignited at 1,000° C. in air. The boat was introduced to the hot portion of the combustion tube and given a preheat time of 2 minutes, during which time the ingoing oxygen flow was continually adjusted to avoid "suck backs" from the sulphur absorption vessel. The exit gas flow rate was then adjusted to 300 ml./min. When approximately 400 ml. of gas had passed to the Ströhlein unit, i.e. when the displacement liquid level reached the zero mark (at atmospheric pressure) of the burette, the oxygen flow was by-passed to atmosphere for a further 1 minute period. The boiling tube was disconnected and titrated with N/200 iodine solution, and the carbon was determined simultaneously by manipulation of the Ströhlein unit, i.e. by absorbing the carbon dioxide in 40% caustic soda solution and making the usual corrections for barometric pressure and temperature. The foregoing procedure was applied to several B.C.S. standard steels and the results are presented in Table I.

Discussion of Experimental Results

Relationship between Rate of Sulphur Evolution and Oxygen Flow Rate (No Preheat)

It is common experience that the efficient determination of sulphur in steel by combustion requires a high combustion temperature, and it was decided therefore to use a constant temperature of 1,280° C. in the present investigation. This temperature is commonly used, since it is sufficiently high for sulphur determinations and does not involve undue combustion tube and furnace deterioration.

As explained earlier, the use of a Ströhlein unit renders important the total volume of excess oxygen required to evolve and carry the sulphur and carbon oxides to the absorption train. For this reason it is desirable to derive a relationship between the rate of sulphur evolution and exit oxygen flow rate during combustion, and the data obtained on a standard steel (B.C.S. 218/1) are plotted in Figs. 1–4. The triplicate results at any of the constant flow rates show good agreement, particularly when the speed of titration and burette reading are taken into account. Flow rates in excess of 400 ml./min. were not examined, since they would obviously not produce a significant increase in sulphur evolution rate and might result in incomplete sulphur absorption.

When the time intervals required for complete sulphur evolution are plotted against exit oxygen flow rate (Fig. 6), the data may be approximately represented in the ranges investigated by a rectangular hyperbola. This is not unexpected, since the observed sulphur evolution rate is the consequence of two main steps, viz : evolution from the steel sample which, in the presence of excess oxygen, is probably very rapid and only slightly dependent on oxygen flow rate ; and, finally, transference of the sulphur oxides to the absorption tube. If these assumptions are true, the over-all reaction is probably mainly dependent on the time required to purge the sulphur from the dead space of the combustion tube, and this time is approximately related hyperbolically to flow rate, as shown elsewhere[5] by one of the authors when discussing purging rates.

The hyperbola best suited to the data in Fig. 6 has the equation :—

$$T \times R = 600$$

where T is the oxygen flow time for complete sulphur evolution (min.), and R is the oxygen flow rate (ml./min.), and it appears therefore that under the experimental conditions and range described above, 600 ml. of oxygen (i.e. oxygen and carbon and sulphur oxides leaving the

TABLE I.—ANALYTICAL RESULTS FOLLOWING APPLICATION OF COMBINED CARBON AND SULPHUR PROCEDURE TO STANDARD STEELS.

Standard Steel Sample	Certified Values		Combined C & S Technique	
	C%	S%	C%	S%
B.C.S./218/1	0·155	0·045	0·15 0·16 0·15 0·16	0·045 0·046 0·045 0·044
B.C.S./239/1	0·220	0·025	0·22 0·21 0·23	0·025 0·025 0·025
B.C.S./225/1	0·355	0·012	0·36 0·36	0·012 0·013
B.C.S./215/1	0·925	0·036	— —	0·036 0·034

combustion tube) is required for complete sulphur evolution regardless of oxygen flow rate. The choice of flow rate is therefore concerned essentially with the optimum speed of sulphur evolution, and not with the total volume of oxygen required. Rates above approximately 300 ml./min. do not result in significant increases in sulphur evolution rates. In the absence of preheat, and using a 400 ml. capacity Ströhlein unit, a further passage of 200 ml. oxygen would be required after filling the unit, to ensure complete sulphur evolution.

Effect of Preheat

The use of a 2 minute preheat makes it necessary to distinguish between the total combustion time and the time period during which an exit oxygen flow is maintained. The amount of excess oxygen required to effect complete sulphur evolution is best considered from Fig. 6. This shows that a 2 minute preheat time decreases the oxygen flow time for complete sulphur evolution by approximately 0·41 minutes, regardless of oxygen flow rate. Fig. 7 shows the implications of this ; whereas in the absence of preheat, the volume of oxygen required (600 ml.) is independent of flow rate, the use of a preheat involves a steady decrease in the volume of oxygen required as the flow rate increases. High flow rates are therefore beneficial in that they reduce the extra purge required to ensure complete sulphur evolution after filling the Ströhlein unit.

A marked disadvantage of the use of a preheat period is illustrated in Fig. 8, where total combustion time is plotted against oxygen flow rate. At every flow rate examined, the combustion time is increased by approximately 1½ minutes, by using a 2 minute preheat.

To sum up, the introduction of a 2 minute preheat reduces the amount of oxygen required for complete sulphur elimination, but at the same time increases the over-all combustion time.

The above data, including the effect of a 2 minute preheat, may be used to draw up a method of analysis suitable for any particular type of Ströhlein unit, volume and operating conditions. Thus, if it is of great importance to determine carbon and sulphur as rapidly as possible, and if there is no difficulty with continuing to sweep out sulphur simultaneously with the manipulation of the Ströhlein unit, then the preheat should be omitted

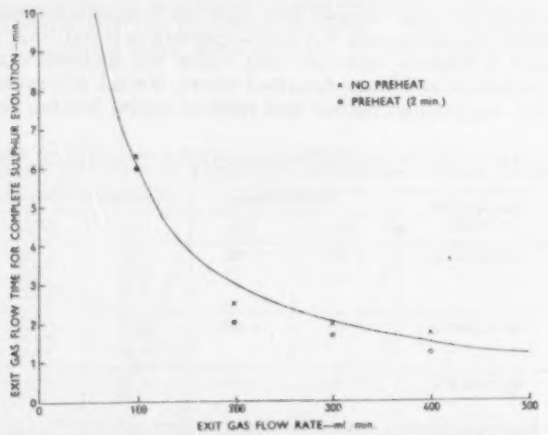

Fig. 6.—Exit gas flow time for complete sulphur evolution v. exit gas flow rate.

and when the Ströhlein is full, the extra purge time for sulphur (to give a total gas volume of 600 ml.) should be continued, diverting the excess oxygen to the atmosphere. If it is desired to reduce the extra purge time, i.e. to reduce the total volume of exit oxygen required, a 2 minute preheat is required, but this increases the over-all combustion time.

It is apparent that oxygen flow rate has so far been considered only from the point of view of sulphur evolution. The reason for this is that common experience shows carbon to be rapidly and efficiently evolved at the higher flow rates (300–400 ml./min.) investigated, and that conditions which are suitable for sulphur evolution are at least as acceptable for carbon determinations. Although a few combined sulphur and carbon determinations have been made to show this fact they were undertaken particularly to illustrate how the above data might be used to design a combined sulphur and carbon analytical technique.

Combined Sulphur and Carbon Determinations

The technique used has already been described, but some explanation of the exit oxygen flow rate, extra

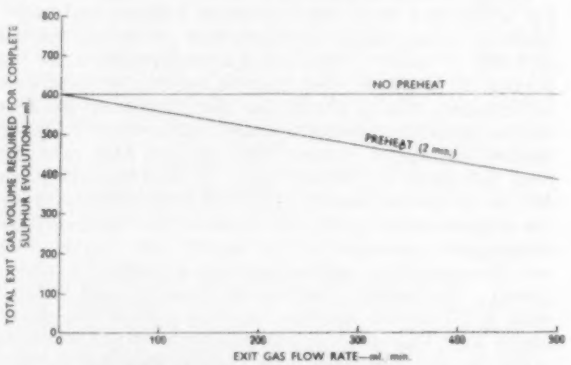

Fig. 7.—Total exit gas volume required for complete sulphur evolution v. exit gas flow rate.

purge time, etc., used is required. It was decided to adopt an exit oxygen flow rate of 300 ml./min., since this was well within the flow rate range giving complete sulphur absorption, and at the same time resulted in a reasonably rapid combustion time. By using a 2 minute preheat, the total exit gas volume was cut from 600 ml. (no preheat) to approximately 475 ml. (see Fig. 7), and thus an extra purge time of *ca.* 30 seconds was required after filling the Ströhlein unit (capacity 400 ml.). In practice the Ströhlein unit was manipulated during the extra purge time, and the latter was increased to 1 minute without any time loss. The ultimate conditions were, therefore, a 2 minute preheat, an exit oxygen flow rate of 300 ml./min., and a 1 minute extra purge time.

The analytical results shown in Table I illustrate the reliability of the combined carbon and sulphur technique. It should be emphasized, however, that several other techniques, some omitting the preheat, are equally acceptable, and the above procedure is merely one example of the use of the oxygen-flow-rate/sulphur-evolution data supplied.

Conclusions

(1) When 1 g. of steel is combusted at 1,280° C. in

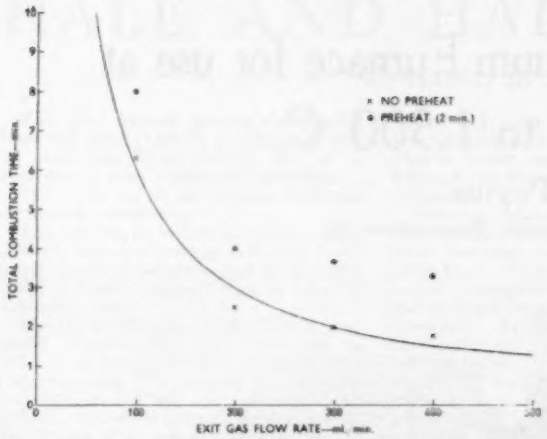

Fig. 8.—Total combustion time v. exit gas flow rate.

oxygen (no preheat) using the combustion train described, the combustion time required for complete sulphur evolution decreases as the exit oxygen flow rate increases. Further decreases are small when the oxygen flow rate attains approximately 300 ml./min. The total volume of exit gases required for complete sulphur evolution is approximately 600 ml., regardless of oxygen flow rate.

(2) The use of a 2 minute preheat time increases the over-all combustion time but reduces the total volume of exit gases required for complete sulphur evolution. Thus at an exit flow rate of 300 ml./min., only approximately 475 ml. of gas is necessary.

(3) As an example of the application of the above data, a suggested method is described for the simultaneous determination of carbon and sulphur utilising a Ströhlein unit. Results obtained on standard steels illustrate the reliability of the technique.

Acknowledgments

The authors desire to acknowledge the considerable practical assistance given by Mr. G. Goddard. They also to thank Mr. R. A. Hacking, O.B.E., Director of Research, Richard Thomas & Baldwins, Ltd., for permission to publish this paper.

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Correspondence

Hump Back Furnaces

The Editor, Metallurgia.
Sir,

I have read with very considerable interest the review in your June, 1959 issue, covering developments in heat-treatment equipment and congratulate you on the field covered. An article such as this shows, if proof were required, that British furnace manufacturers are well ahead in providing equipment to enable the British engineering industry as a whole to benefit from new or improved metallurgical materials. In fact, this progress is in part due to the improved heat-treatment equipment made available as it is needed.

There is, however, one impression I feel should be corrected. Reference is made to mesh belt furnaces for bright annealing, normalising or brazing, which it is stated include the new "hump back" furnace, a design which reduced considerably the consumption of hydrogen in protective atmospheres. I think it should be recorded that this Company introduced "hump back" furnaces for this precise reason as long ago as 1939, since when we have supplied a considerable number of furnaces of this type. The photograph shows the original "hump back" furnace which enabled a saving of approximately 60% in the protective atmosphere consumption to be effected when compared with the normal horizontal type of furnace.

Yours faithfully,
J. E. Oram, Managing Director,
Wild-Barfield Electric Furnaces, Ltd.
Watford.

September 21st, 1959.

It is regretted that the publication of this letter has been deferred for reasons of space—*Editor*.

A. P. Newall and Co., Ltd., of Glasgow, manufacturers of Hitensile and Newalloy bolts and studs have placed an order valued at £33,000 with Electric Resistance Furnace Co., Ltd., for continuous, automatic, heat treatment plant for the hardening and tempering of nuts and bolts. The plant, which will be one of the largest bolt hardening and tempering installations in Britain, will include Efco cast-link and mesh belt conveyor furnaces, a quench tank, and an endothermic atmosphere generator.

A Laboratory High-vacuum Furnace for use at Temperatures up to 1,500° C.

By G. T. Poyner

(The B.S.A. Group Research Centre, Birmingham, 33)

A FEW years ago this laboratory became deeply involved in the development of high-temperature alloys produced by powder-metallurgy techniques. The presence of aluminium and titanium in these alloys made vacuum sintering essential to ensure low final oxygen contents and to permit full densification. Suitable small vacuum-type furnaces did not appear to be commercially available. Thus, the development of a small furnace, with a capacity suitable for sintering small blanks from which miniature stress-rupture and fatigue test-pieces could be machined, was undertaken.

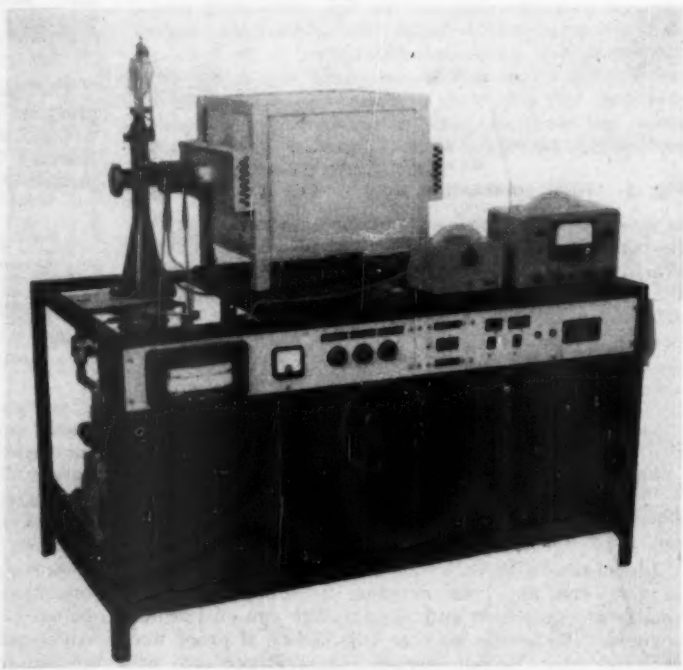

Fig. 1.—The complete high-vacuum furnace

Description of Furnace Unit

A general view of the furnace is given in Fig. 1. It comprises a modified tube furnace to which is connected standard vacuum-pumping equipment, using a conical adaptor. A minimum number of vacuum seals and a minimum amount of water-cooling apparatus are features.

The furnace consists of a steel frame, faced with Syndanyo and containing hot-face insulation bricks. A cylindrical heating cavity within the insulation contains six Morgan Crusilite heating elements spaced equally around, and parallel to, a refractory tube of 42 mm. inside diameter. A Degussa recrystallised, alumina tube (AL23) was adopted because of its very low gas leak-rate and its high mechanical load-carrying capacity at the required temperature. Thermocouple contamination can be reduced to a minimum by using recrystallised alumina thermocouple sheaths of 3 mm. inside diameter extending over the whole length of the thermocouple. Electrical power to the furnace is derived from a 20 A. Variac and switched by a double-pole mercury relay which, in turn, is operated by an anticipatory temperature-controller. The effective "hot-zone" length depends upon the desired accuracy. A variation of ± 3° C. is obtained over the 3 in. central zone.

The vacuum system comprises a 2 in. fractionating diffusion-pump, backed by a 2 cu. ft. gas-ballasted rotary pump, and a vacuum of better than 0·1 micron can be attained. The vacuum system is connected to the furnace-tube by a water-cooled sleeve which is attached to the conical adaptor tower containing the loading port, ionisation gauge head, and the thermocouple terminal plate. All seals are made with rubber O-rings.

The original furnace unit has been in successful operation for over three years. During this period further improved furnaces have been produced, and they have been found to be ideally suited for general vacuum work; only minor troubles have been experienced. The use of separate heating-elements has enabled the few necessary replacements to be carried out rapidly and conveniently. This type of furnace should therefore interest many laboratories; and, on this account, Messrs. General Engineering Co. (Radcliffe), Ltd., have agreed to make the furnace-unit available commercially.

Acknowledgments

The author's thanks are due to Messrs. V. A. Tracey and F. W. Newell, for considerable assistance during the development of the furnace.

X-Ray Equipment Agency

PANTAK, LTD., of Vale Road, Windsor, Berks., have recently concluded an agreement with Usines Balteau of Liége for the marketing in the U.K. of two ranges of lightweight portable industrial X-ray equipment. This equipment will complement their existing mobile units and will consist of two oil-insulated units of 140 and 200 kV. capacity and three gas-insulated units of 150, 180 and 300 kV. capacity, the 180 kV. unit being specially developed for examining of circumferential welds, etc.

HALE AND HALE (TIPTON) LTD

Progress in a Difficult Year

The 23rd annual general meeting of Hale and Hale (Tipton) Limited was held on December 18 at Dudley, Mr. R. C. Leppington (the chairman), presiding.

The following is an extract from his circulated statement :—

The year under review has been a most difficult one, but despite this your Company has made progress, and the position today is much healthier than it was this time last year.

The Group Trading Profit for the year ended August 4th, 1959, amounts to £92,151, as compared with £93,689 for the previous year. The charge for taxation amounts to £19,566, as compared with £22,638, and there remains a consolidated Net Profit, after various adjustments, of £26,219, against £18,884, an improvement of £7,335. After deducting Dividends and Appropriations the balance carried forward is £26,627, as compared with £23,660 brought forward.

Shareholders have already been advised that the Company had a substantial holding of shares in the Midland Employers Mutual Assurance Co. Ltd., and these shares were included in the Balance Sheet at cost price of £309. Since the date of the Balance Sheet these shares were exchanged for shares in Eagle Star Insurance Co. Ltd., which were subsequently sold to produce a Capital Profit of £146,648. Your Directors recommend that a Capital Bonus of 3/– per share should be paid to the Ordinary Shareholders out of this Capital Profit, and the Balance will be retained for future development of your Company.

Since the relaxation of purchase tax on commercial vehicles in the last Budget, there has been a steady increase in our order book. Within the industry demand is now overtaking productive capacity, and delivery dates are being continually extended. Although our foundries are now very busy, profit margins are insufficient when compared with the hazards of the malleable industry. We are still suffering from depressed selling prices, which are a legacy from the period of recession ; but it is anticipated that with increased demand for our product, prices will rise to a more economic level.

The improvement in commercial vehicle output has acted as an impetus on other trades, and the demand in most sections of industry is increasing.

Your Board feels confident of the future, and plans for the modernisation and development of our plant are well in hand.

SUBSIDIARIES

CHATWINS LIMITED : In company with other solid fuel manufacturers, this subsidiary has experienced a continued falling off in demand for most of its products, being largely brought about by the changing pattern in the domestic heating and cooking field. It is believed by the Management that great changes will occur in the solid fuel industry over the next few years, and in this regard, the possible entry into other fields of manufacture is under review.

J. & J. WHITEHOUSE (TIPTON) LIMITED : This subsidiary is still experiencing difficulty in recruiting suitable labour, but despite this, it continues to hold its own. Cast Iron Hollow-ware for the export trade is produced by the Company under the trade name of " Phoenix."

HALE ENAMELLERS LIMITED : This subsidiary has done remarkably well during the year resulting from greater diversification of production, and there appears to be no slackening off at the moment.

J. WAKEFIELD & SONS LIMITED : During the year we moved this subsidiary from Birmingham and accommodated it in the premises of Chatwins Limited at Tipton. Personnel has been changed, and we are confident that the future will bring worthwhile results. The company manufactures paraffin heating and lighting appliances.

The report was adopted, and the final dividend of 15% (making 20% for the year) and the Capital Bonus were approved.

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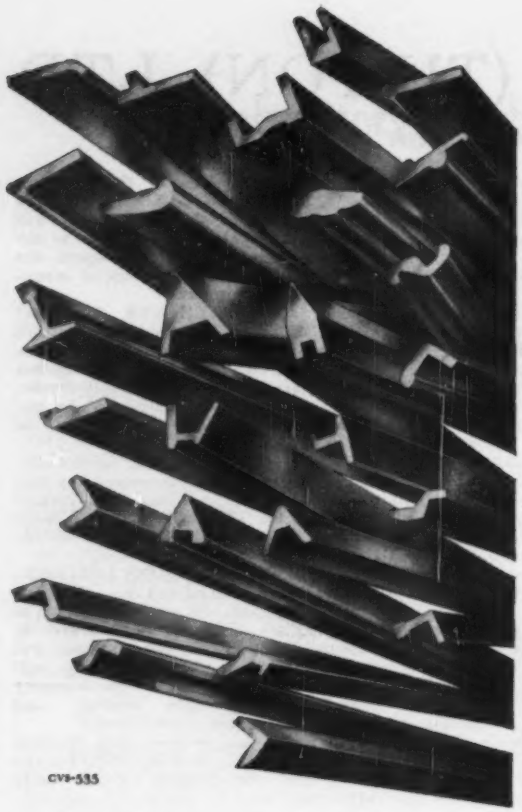
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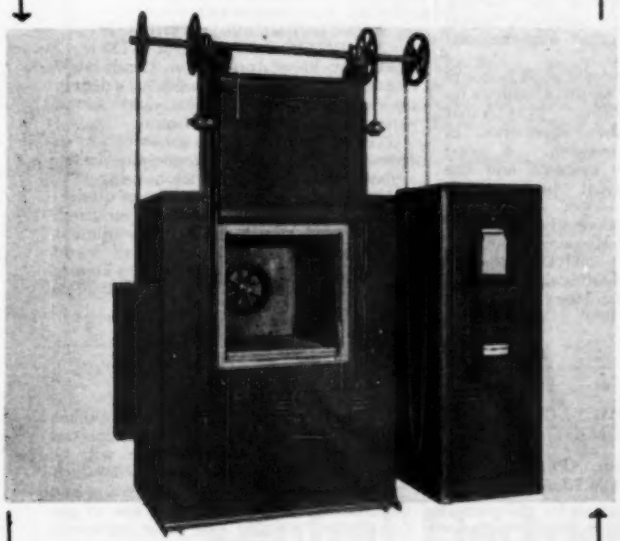

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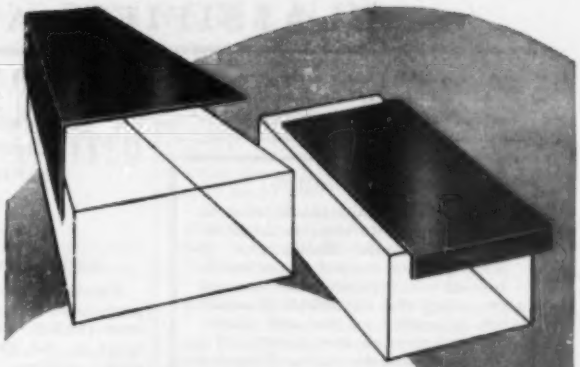

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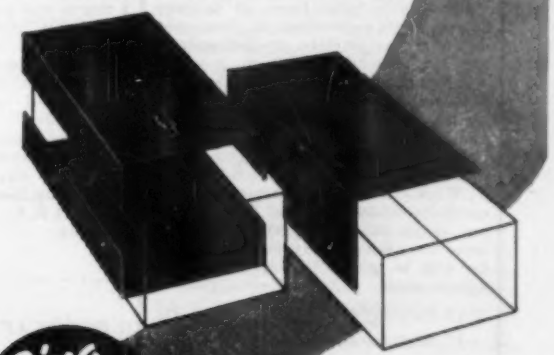

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C. MIDDLETON,
Secretary to the Joint Committee

SITUATIONS VACANT—*continued*

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SITUATIONS VACANT—*continued*

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(2) In addition, several vacancies exist for Assistant Chemists of Higher National or equivalent standard for work in the same field.

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SITUATIONS VACANT—*continued*

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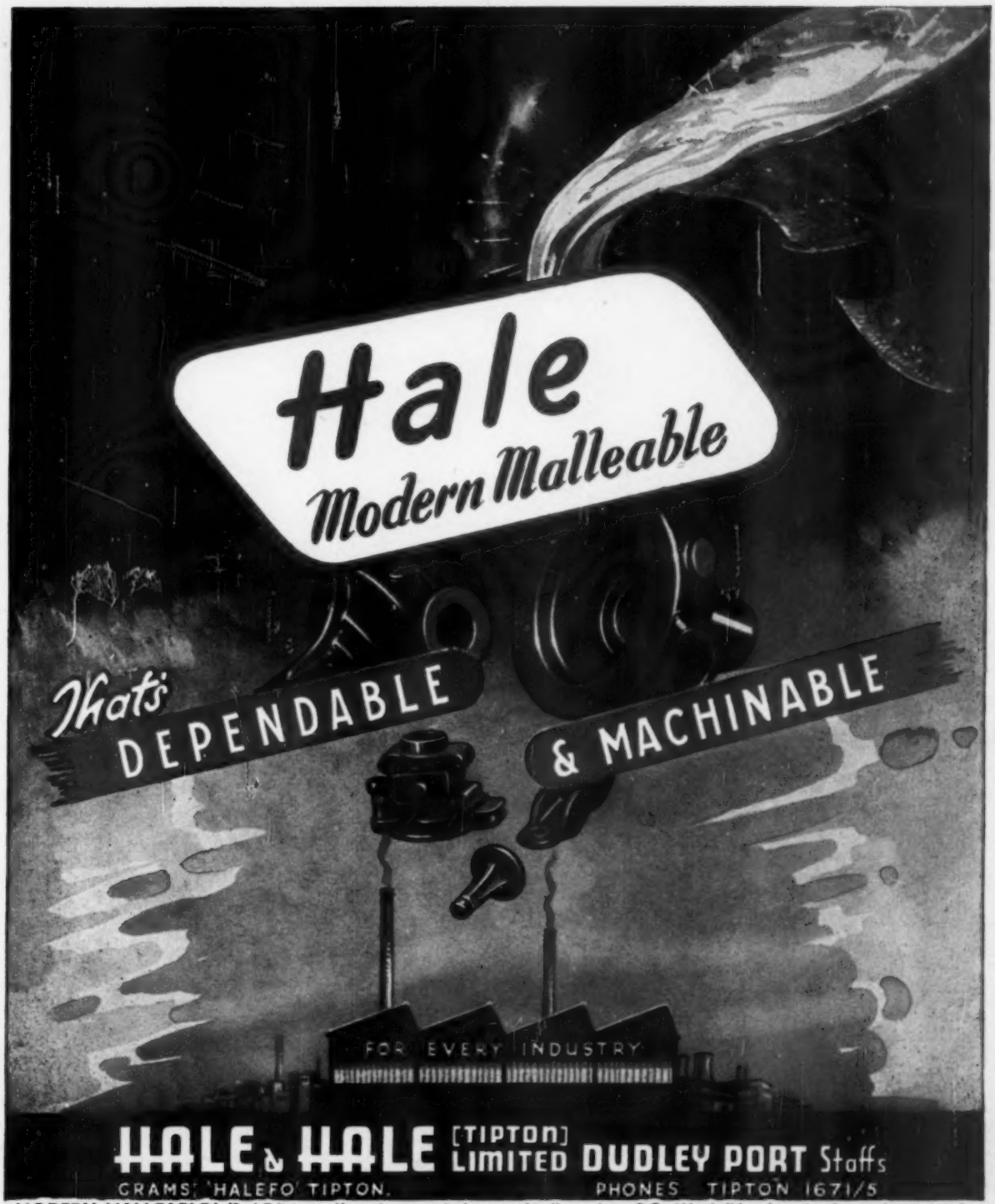

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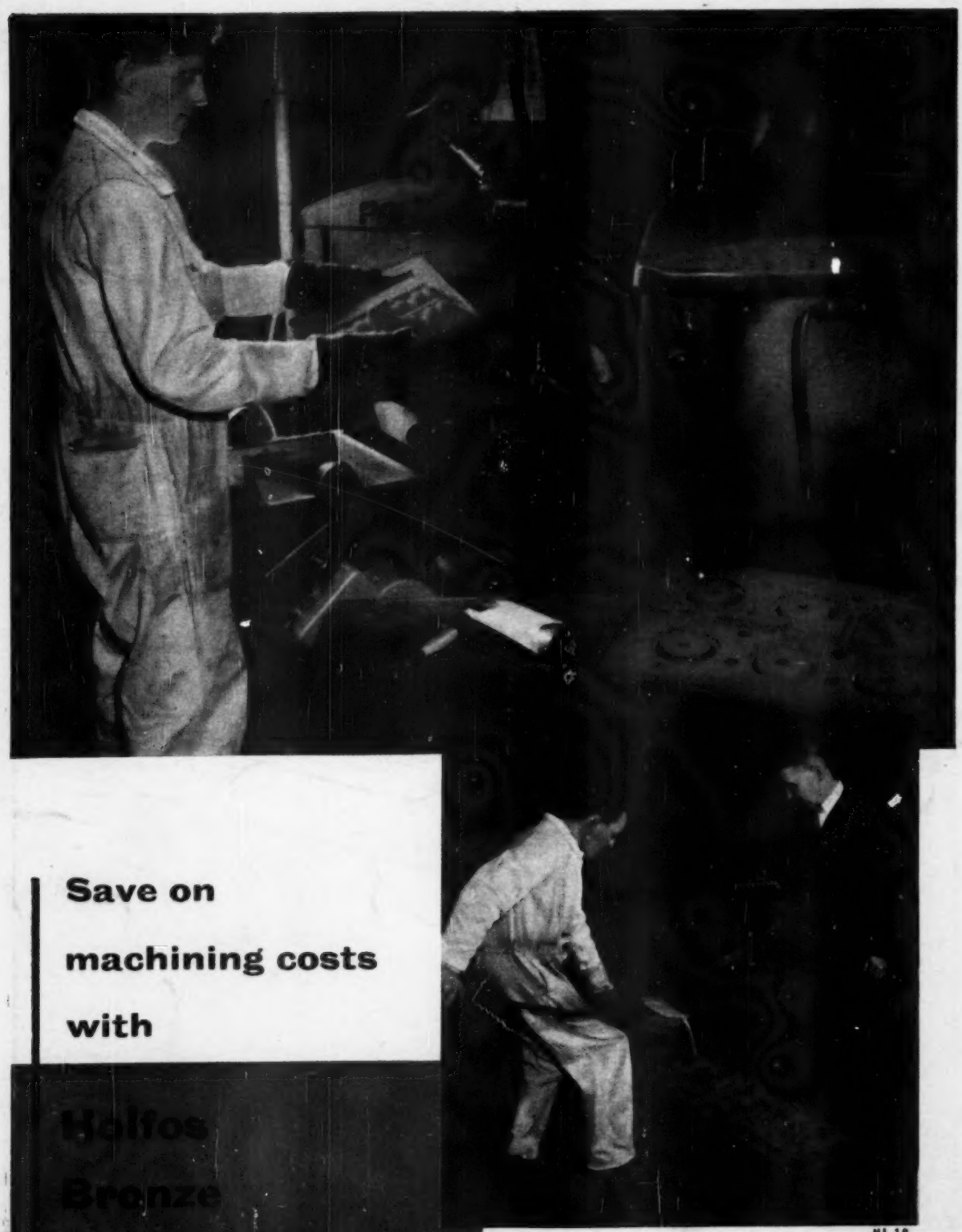

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